COMPACTION CHARACTERISTICS OF A-6 LATERITIC SOIL - RIVER SAND MIXTURE

BY

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PGD/CIVIL/2009/2010/069

DEPARTMENT OF CIVIL ENGINEERING
FERERAL UNIVERSITY OF TECHNOLOGY
MINNA

MARCH, 2012

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A PROJECT SUBMITTED TO THE POST GRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE POST GRADUATE DIPLOMA IN CIVIL ENGINEERING

MARCH, 2012

DECLARATION

I here by declare that this project titled: Compaction Characteristics of A-6 Lateritic Soil - River Sand Mixture is a collection of my original research work and it has not been presented for this qualification any where. Information from other sources (published or unpublished) has been duly acknowledged.

....

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MINNA,

CERTIFICATION

The thesis titled: Compaction Characteristics of A-6 Lateritic Soil-River Sand mixture by: Abubakar Haruna Abdullahi PGD/CIVIL/2009/2010/069 meets the regulations governing the award of the Post Graduate Diploma of the Federal University of Technology, Minna and it is approved for its contribution to scientific Knowledge and literary presentation.

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DEDICATION

I hereby dedicate this research work to prophet Muhammad (PBUH), and to my parents and members of my family.

ACKNOWLEDGEMENTS

All thanks, glorification, praises and worship belongs to Almighty Allah who guided and protected me through out the period I took in undertaken this project work. I can not thank Him enough for the mercy strength, wisdom, knowledge and support given to my life which actually made it possible for the completion of this research work. I appreciate the efforts of my parents and entire family for their keen support. Also, I appreciate the efforts of my brother Arc.

Lawal Usman and Managing Director, Z. B. C. C .NIG. LTD. Alhaji Adamu Hussaini for their support.

Much gratitude to my able supervisor Engr. M.A Mustapha (MNSE) for his advice, guidance and constructive criticism to ensure that this project recorded a huge success. I can not thank you enough Sir. I also wish to express my gratitude and appreciation to the H.O.D, Civil Engineering Department for his fatherly advise and encouragement .I also thank all the entire lecturers in the department among whom are Engr. Prof. O.D. Jimoh, Engr. Dr. J.I Aguwa, Engr.Dr.T.Y Tsado, Engr.Dr.P.N.Ndoke, Engr.Dr.Amadi A, Engr. Dr. Abdullahi M., Engr R. Adesiji, Engr. Mrs O. Gbadebo, Engr. Hafis Busari, Engr.James O, Engr. S.Kolo, Engr.M.Kudu, Engr.Bala Alhaji, Engr,Abdulkadir, Engr. O.I. Jimoh, Engr. Saidu M, Mr. S. Adeniyi, Mall. D. Zango, Mall. S.M Ihyasu and Mall. Umar Moh'd Badeggi. I appreciate your efforts and contribution to my success sincerely.

My big appreciation once more to my lovely wife, children, brothers and friends for their love, caring and support accorded to me during the course of my study. May Allah (SWT) reward you all abundantly (Amen).

Finally, my gratitude and appreciation goes to my entire classmates for their understanding, maturity and cordial relationship which made it possible for this huge success.

ABSTRACT

Soil sample collected from Gidan Kaji Village, Niger State was classified as A-6 soil by American Association of State Highway & Transportation Officials (AASHTO) and clay of low plasticity (CL) by Unified soil Classification System (USCS), was mixed with River sand collected from a construction site. Strength properties of the mixture were investigated at Modified AASHTO energy level. The sand were mixed at 0, 5, 10, 15, 20, 25..........and 100% of river sand each by weight of the lateritic soil. Results showed that the Maximum Dry Density (MDD) increases from 0% at 1.935g/cm^3 to 95% at 2.085g/cm^3. the percentage increase is 7.2%. While the Optimum Moisture Content (OMC) decreases with increasing river sand as from 0% at 12.8% to 85% at 10.7%. the average percentage decrease in OMC is 23.64%.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Preamble

For engineering purposes, soil is considered to be any loose sedimentary deposit such as gravel, sand, silt, clay or mixture of these materials. According to (Craig,1992) soil is any uncommented or weakly cemented accumulation of mineral particles formed by the weathering of rocks.

The weathering process could be associated with mechanical, chemical and biological forms. When the end product of weathering remain at their original location, residual soil is said to be constituted but if the end product are transported and deposited in a different location they constitute a transported soil. Weathering alters the composition and structures of rocks by either chemical or physical means. Physical weathering causes disintegration of the rocks into smaller particle sizes through its various agents such as erosion, temperature variations, freezing and plants and animal activities. Chemical weathering, on the other hand, can be attributed to the decomposition of minerals in rock by oxidation, reduction, carbonation etc. Therefore soil is an important material in engineering particularly to civil Engineers. Soil encountered close to the earth surface is one of the most important and widely used engineering materials because most of construction works are founded in on the surface of the earth. In tropical regions the conventional material used as base and sub base for road works are the lateritic soils. (Terzaghi Etal, 1967).

Laterites are usually light to dark red in colour and composed almost entirely of iron and aluminum oxides, titanium, manganese and silica which harden on extraction and exposure (MC Gearg Etal 1998). Most of lateritic soils contains kaolinite and quartz which makes their engineering performance to be poor. Therefore there is very need for such lateritic soils to be stabilized using locally available and cheap stabilizing materials.

Soil stabilization is aimed to improve the soil strength and durability so that they can be more suitable for construction purposes beyond their classification if left unsterilized. In short, stabilization alters the engineering properties of the soil to improve its engineering performance.

The main factor that affects stabilization of soils is compaction energy. This work is therefore aimed at determining the compaction characteristics of an A-6 lateritic soil mixed with river sand.

1.2 Location of the Study Area.

The lateritic soil used for this research work was obtained from a borrow pit in Gidan kaji, a village five kilometers away from Minna along Kuta road, Niger State.

1.3 Aim and Objectives

The main aim of this research work is to determine the compaction characteristic of laterite-river sand mixture through these underlisted objectives

a. laterite is obtained from a known borrow pit, air-dried and index properties test were carried out to aid classification.

b. River sand obtained from construction site is tested for particle size distribution and specific gravity.

c. The river sand will be mixed at 0,5,10,15,20,25...........and 100 percent by the weight of lateritic soil

d. These Mixtures will be compacted using modified AASHTO methods of compaction in order to obtain their Maximum Dry Density (MDD) and Optimum Moisture Contents (OMC) and to observe their variation with addition of river sand.

1.4 Justification

Though, lateritic soil is widely used as a construction materials because of its availability, quite a number of laterites are not normally suitable for uses in their natural state and therefore need an improvement. Soil improvement could be by stabilization or modification. The common materials used for soil stabilization are cement, lime and bitumen All these materials are expensive while some are not even widely available. However, river sand is available and relatively cheap. It is therefore justifying to evaluating the compaction characteristics of an A-6 lateritic soil and river sand.

1.5 Scope of Study

This research involves characterization of natural lateritic soil so as to classify it according to American Association of State Highways and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS) soil classification and the river sand. The river sand is then mix with lateritic soil at 0, 5,10,....to 100% by weight of the lateritic soil. Compaction test will be carried out on all the mixtures to determine its compaction characteristics. The compaction characteristics will then be plotted to obtain the variation of the characteristics with change in river sand.

CHAPTER TWO

2.0 LITERATURE REVIEW

Lateritic soil constitutes an important soil group in the tropics and mostly used for construction purpose.

However, before discussing the laterite, there is need for us to understand more about the term "soil". The term soil has various meaning and carries different sense to different professional groups. From the engineering perspective soil can be defined as the earth crust or it comprises of all minerals (or materials) found in the surface layer of the earth crust that are loose enough to be removed by spade or shovel. Such materials are normally composed of solid, liquid and gaseous phases.

Moreover, soil can be said to be the product of disintegration of rocks due to action of chemical and mechanical forces, which have been exerted upon the parent rock. These forces include running water, wind, freezing and thawing, chemical decomposition, glazier action and others (Co-right and Paquete, 1979).

Soil as a civil engineering material is as important as concrete and steel because all man-made structures, except those which float or fly are supported by natural soil. Civil engineering structures such as water retaining wall, air field pavement and roads are constructed from soil and rock materials and other materials that can be used for the same purpose (Barnes, 2000).

Towards the end of eighteenth century, the first major contribution to the present scientific study of soil behavior was established by Coulomb (1776). The writer published his wedge theory of earth pressure and was the first who discovered that the shearing resistance of soil is composed of two components namely, cohesion and friction. Thereafter Darcy's law for flow of water through soils and Strocks law for settlement of solid particles in liquids (1856) were presented. These laws play an important role in soil engineering to date. Rankine presented his theory for calculating earth pressure and safe bearing capacity of foundation in 1857. In the nineteenth century, Boussinesa (1885) presented his analysis for stress distribution in semi-infinite, elastic medium under surface point load.

In general, the basic physical properties of soil were understood at the beginning of twentieth century through the work of Alterberg (1911), a Swedish soil scientist. The writer was the first to establish in (1911) the different stage of consistency in which a clay soil may exist depending upon its water content. Terzaghi (1923) published his theory of consolidation and the term soil mechanics was found by him in (1925), when his book under the equivalent German title Erdbanmechanic was published. Recently, in (1933), the contribution of proctor on the principle of soil compaction was acknowledged.

The classification of soil according to Holtz and Kovacs (1995) is the system that represents the effective language communication between the engineers. It also provides the method of categorizing the soil according to their engineering behaviours, and allows engineers access to the accumulated experienced of other engineers. The classification system is not enough to eliminate the need for detail soil investigation or testing for engineering properties. However, the engineering properties have been fond to correlate with the index and classification properties of a given soil. The most common systems of classification used today in civil engineering practice (Holtz et al 1995) are Unified Soil Classification System (USCS) and the American Association of State Highway and Transportation Official (AASHTO).

The importance of soil in terms of its usage can not be over emphasized, as it is the most available, cheapest constructional material throughout the world. It is widely used in construction of transportation facilities, water retention structures, dwelling and monument tombs (Lamb et al, 1979).

Soil is also used for reclamation project where large sites are built by filling through the process known as hydraulic filling. It is commonly used again as construction material in the pavement of road and air fields. The material used for construction of earth reservoirs and containers for storage of industrial fluids such as refrigerated liquefied gas is predominantly the soil (Lambe et al, 1979)

2.1 Laterites

The name laterite was derived from the latin word "later" meaning brick and the term was first used to described soil by Buchama, 1807 in southern India. The word laterite described materials with no reasonable constant properties. It signifies a different material to different part of the world.

There were a lot of diverse definitions of laterite simply because of its engineering and geotechnical properties. Among the definitions that has wide acceptance in 19^{th} century is that of Gidigasu 1976 which defined laterite in terms of silica sesquioxide ratio. Although the definition lost its recognition later because it does not established any relationship with engineering properties of laterite. Buchaman (1807) used the term laterite to describe the reddish ferruginous, vesicular, Unstratified and Procus materials with yellow Ochres occurring extensively in Malabar, India. Some definitions have been made on the basis of the relative content of the hydroxide they contain (Lacroix, 1913), of the silica-alumina ratio, $si0_2/Al_2\ 0_3$ (Matrtin and Doune, 1941), or in terms of Mature and Inmature Soils (Pendleton and Sharrasullma, 1946). Others include that of Lynon associated inc (1971) which use the silica to sesquioxide ratio as basis for definition as follows:

$SiO_2/ fe_2 Al_2O_3$. The researcher stated that if the ratio is less than 1.33, the soil is termed true or pure laterite, between 1.33 and 2.00 is termed as lateritic soil while those that are greater than 2.00 is termed non-lateritic soil. The above definition by Lynon associate inc (1971) is found not convenient from an engineering point of view, particularly in developing countries where there is lack of laboratory facilities. The author therefore went on to define lateritic soil as a product of tropical weathering with reddish-brown or dark-brown color and generally (but not exclusively found below hardened ferruginous crust or landscape). Laterite and lateritic soil form a group comprising a wide variety of red, brown and yellow fine-grained residual soils of light texture as well as nodular gravel and cement soils. They may vary from loose materials to a massive rock and they are characterized by the presence of iron and aluminum oxides or hydroxides, particularly those of iron gives color to the soil for engineering purposes. Laterite soil can also be refered as the materials with low concentration of oxide (Newill and Dowling, 1990). Ola (1983) defined the lateritic soil as all product of tropical weathering with red, reddish brown or dark colour with or without nodules or concretions and generally (but not exclusively) found below hardened ferruginous crust or hard pan. An all- encompassing definition by Gridigasu (1975) is seen to include four of the great soils groups defined by Thorp and Smith (1941) as follows. (i) The reddish brown lateritic soil (ii) Yellowish brown lateritic soil (iii) Lateritic soils and (iv) Ground water lateritic soils.

However, Hunt (1984) had earlier identified specific regions in the middle latitudes which include much of Brazil, the southern part of Africa, southern Asia and part of India as specified regions where laterite deposit could be found. The researchers also identified laterites as not always trouble some since they consist mainly of kaolin clays, which are relatively inactive and non-swelling.

2.2 Properties of Laterites

The higher the proportion of sequioxide relative to other chemical components is a feature characteristic of all grades of laterite soil. Two groups of laterite materials are chemically identifiable according to (Sherman, 1952).

1. Those groups in which the iron oxide predominate (ferruginous laterite soils) and
2. Those which alumina predominate (aluminous laterite soils)

The common chemical composition of laterite according to Gidigasu (1976), Ola (1983), Osumbi (2003), are silica ($Si0_2$), sequioxide of iron (Fe_20_3) and aluminium ($A1_20_3$). Other common chemical constituents of laterite soils are oxides of manganese (Mn), titanium (Ti), chromium (Cr), and vanadium (V). Titanium oxides does not commonly occur in reasonable amount in most varieties but it may sometimes be a major constituent in some laterite soil (Sherman,1962). Silica is low in most lateritic soil deposits but higher amount are found in few deposits where parent rock contains a lot of quartz. The West African laterite soil according to (Gidigasu, 1976) reported the presence of higher sequioxide of between 20-50 % against black clays, which possess less than 20%. The presence of sesquioxide particularly that of iron (Fe_20_3) imparts on the laterites, the property of hardening on firing. This was confirmed by Adeyemi et al (1990) who conducted a research work on laterites collected from three different areas in the southern Nigeria, aiming at evaluating the strength of both air dried and fire bricks made of these laterite clay deposits. Observation shows that firing increases the compressive strength of laterite collected from the first area by three times compared to that of air –dried one. While those of the remaining two areas increased in strength by eight times compared to the air dried one. The wide variation in the compressive strength of the last two areas is due to higher iron oxide (fe_20_3) content of the lateritic soil deposit.

However, the geotechnical characteristics and field performance of most laterite soils are influenced considerably by genesis, degree of weathering, morphological characteristics, chemical and mineral composition as well as environmental condition (Osunbi, 2004). Though, the terminology used to described the properties of lateritic soil are not standardized but the geotechnical properties of its cohesion, resistance to stress, moisture relationship, susceptibility to value change and reaction to various kind of additives are in co-operated for the purpose of moisture and strength stabilization (Osunbi, 2004).

2.3. Classification of Laterites

Different researchers used different approach to the classification of laterites. Some researchers based their classification on the mode of formation, parent materials and degree of weathering of laterite soil. Mineralogical composition of laterites tends to classify it as problem or non problem laterite, laterite of high strength or low strength, laterites of high construction pore pressures, laterites of high swelling potential and other undesirable properties laterite soil may posses. Other classifications are based on the index properties of laterite soil.

According to (Ola, 1983), most of Nigerian laterites falls between A-1-a and A-7-6 of American Association of State Highway Transportation Officials (AASHTO) classification system. The range of index values of some laterite soil deposits in Nigerian as reported by Madu, (1975) revealed the liquid limits and plastic limits ranges between 45%-57.2% and 22%-40.40% respectively. The plasticity index and shrinkage limits also lie within 16%-24% and 8.6%-14.8% respectively. However, Gidigasu (1976) reported higher value of liquid limit and plasticity index of above 50% and 30% respectively. The engineering properties of soil deposits vary widely in the same manner as its texture. Gidigasu (1976), and Ola (1983), reported California Bearing Ratio (CBR) values as low as 2% for problem laterite to as high as more than 200% for good laterite soil. Maximum dry densities as low as 1.50mg/m^3 to as high as 2.4 mg/m^3 has equally been recorded at British standard light (BSL) compaction energy. It is obvious that the higher the compaction energy the higher the results.

2.4 Mechanical Stabilization of Soil

Stabilization is a term used for improvement of soils either as they exist in situ or when laid and densified as fill. It relies on process of change which directly affects the interactions of earth, water and air in a soil and it allows one to achieve permanent properties which might make a soil suitable for one or more particular applications as a construction/ building material (Valentine,1993). In other word it is the improvement of the soil by the use of controlled compaction proportioning and or addition of suitable admixture or stabilizer. (Justo et al, 2001). Some researchers (Gidigasu, 1976, Ola, 1983, Singh, 1991, AFMAN, 1994) have all defined mechanical stabilization in their various words to mean the mixture of appropriately proportioned soil aggregates with some binders soil like clay or sand, after which the mixture is properly compacted to a stable layer. Moreover, the main purpose of soil stabilization is to improve the soil strength, bearing capacity and durability under adverse moisture and stress condition (Gidigasu, 1976).

In mechanical stabilization, the basic principles involved are proportioning and compaction (Singh, 1991). It is known that aggregates soil mixtures having none or little amount of fine can only be stable under confined conditions due to lack of cohesion between aggregates. These types of materials will have high permeability. Mechanical stabilization of this material with addition of some binder soil like clay would improve the strength and stability of the mixture even under unconfined conditions. But in a situations where by soil deposit is predominantly fine material, the compacted aggregate grains will not be in contact with each other and the stability of the soil is virtually decreased. This situation can be corrected by mechanically adding appropriate proportion of coarse aggregate to the soil in other to improve its strength and stability. However, the improvement of soil with lime does not give the required strength and durability.

It is possible to change two characteristics of a soil, the texture and the structure, and these changes alter three main properties of the soil which are porosity, permeability and the mechanical strength. The objective for changing these two characteristics are:-

i. Reducing porosity and tendency of a soil to swell and shrink
ii. Achieving higher dry and wet compressive strength and shearing strength
iii. Improving resistance to erosion and the water resistance of the surface.
iv. Achieving better cohesion
v. However Singh (1991) highlighted some factor that affect the stability of a mechanically stable layer to include

i. Proper grading: To achieve maximum strength and stability from mechanically stabilized soils, the amount of fines present in the mixture should be sufficient to fill in the voids in the aggregates

ii Properties of the soil to be mixed:- properties of soil affect the strength in mechanically stabilized soil mixture. The higher the plasticity index of the soil included in the mixture, the poor the stability of the compacted mix under soaking conditions.

iii Strength of aggregate in use : if a proper grading is achieved, the strength of the mix will be controlled by the crushing strength of the aggregates. If the crushing strength of aggregates is low, the stability of the mixture will reduced.

iv Amount of compaction :- Being the most important factor in the processes of soil stabilization, researchers like Gidigasu(1976), Ola (1983)/Osinubi (1998), have reported increase in strength of stabilized soils with increase in compaction energy (ie from British standard light (BSL) compaction energy to West African Standard (WAS) compaction energy.

v presence of harmful ingredients:- presence of harmful ingredients like sulphates can affect the compacted mix negatively but presence of salt like calcium chloride could be beneficial (singh,1991).

2.5 Previous Work

In recent years, some researchers have diverted their attention at evaluating usefulness of lateritic soil in building and allied industries, and some useful results were reported form their earlier research. It has been found that the strength of a laterite is a function of grain size and the source of soil (Lasisi and Osunade, 1988). They also reported that the possible geological formation processes are factor in the determination of strength.

As a following studies of the investigation by (Thomas and Lisk, 1971) on the suitability of crusher lateritic rocks for use in both building and road construction, the results indicate that the lateritic aggregates are suitable as roads construction material and concrete aggregate, despite their slightly inferior performance compared with that of igneous aggregates (Madu, 1980). Another researcher (Ola, 1983) reported that the engineering properties of lateritic soils can be improved through some effective means

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The materials used for this project are lateritic soil (passing sieve no 5.00mm)and clear river sand. The lateritic soil was collected from a borrow pit in a village called Gidan kaji along Minna – Kuta road, Niger State while the river sand was taken from a construction site. The method of collection used was disturbed sampling.

3.2.0 Methodology

The methods employed in this research work are in accordance with

BS1377 (1990) and it involves primarily the mixing of lateritic soil with various percentage of river sand that ranges between 0,5,10 to 100%. The test conducted on the mixture was compaction using AASHTO compaction methods. Mean while, index properties test were conducted on lateritic soil alone so as to classify it according to unified soil classification system (USCS) and AASHTO classification method. Although sieve analysis and specific gravity test as were also carried out on river sand.

3.2.1 Soil Classification Test

3.2.1.1 Determination of Natural Moisture Content

The lateritic soil collected from borrow pit was immediately kept in an air tight polythene bag to avoid the escape of moisture and was brought to the laboratory. Two empty cans were cleaned and weighed (M_1). About 30g of moist sample was placed in each of the can, the mass of the cans and the contents were taken and recorded (M_2). It was then placed in an oven at a temperature of 105^0C for a period of 24 hours to dry sufficiently. After drying, the mass of the can and its dry soil content were taken and recorded (M_3). The weight of water in the soil and the weight of dry soil were obtained by differences in weight as shown in the formular and Table 3.1 below.

$$\text{Moisture Content } (W)\% = \frac{M_2 - M_3}{M_3 - M_1} = \frac{M_X}{M_Y} \times 100 \qquad (3.1)$$

Where W= Moisture content in percentage (%)

M_1= Mass of can (g)

M_2 = Mass of can + wet Soil (g)

M_3 = Mass of can + Dry Soil (g)

M_x = Mass of Water (g) and

M_y = mass of dry Soil (g)

Table 3.1 Natural Moisture Content

Trial number	1	2	3
Can Number	A_3	B_1	C_1
Mass of can M_1 (g)	24.2	24.7	27.9
Mass of can + wet soil M_2 (g)	52.4	59.5	57.9
Mass of can + dry soil M_3 (g)	47.8	53.8	53.1
Mass of dry soil M_y (g)	23.6	29.1	25.2
Mass of water M_x (g)	4.6	5.7	4.8
Moisture content W (%)	19.49	19.59	19.05
Average M.C (%)		19	

3.2.1.2 Determination of Specific Gravity

The density bottles with stoppers were washed and dried at 105^0C, cooled and weighed empty with stopper to the nearest 0.01g as M_1. A quantity of representative sample that passes through sieve No. 5.00mm was transferred to the density bottles and the bottles and their contents with stoppers were weighed as M_2. Distilled water was added to cover the soil in the bottle and allowed to be fully soaked. The stoppers were then inserted and the bottle plus the content were shaken together, the stopper was removed again so as to filled the bottle to a 250ml mark. The density bottles and the contents were weighed as M_3. The density bottles content were emptied completely and clay thoroughly. Oven dried the bottles at 105^0C and allowed to cool. Clean the cool oven dried density bottles and filled with distilled water alone to a 250ml mark. Replace the stoppers and take the weight of bottles and contents (distilled water) as M_4.

Specific gravity (Gs) of any material is calculated using the formular

$$G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \qquad (3.2)$$

and the results were presented in the table 3.2 below

Table 3.2 Specific Gravity Test

Samples	Lateritic soil		
Test number	1	2	3
Mass of empty density bottle M_1 (g)	97.5	126.7	114.2
Mass density bottle + sample M_2 (g)	129.9	164.7	148.5
Mass of density bottle + soil + water M_3 (g)	376.5	410.6	394.5
Mass of density bottle + water M_4 (g)	356.6	387.0	373.2
Specific gravity (Gs)	2.59	2.64	2.64
Average specific gravity (AGs)		2.62	

3.2.1.3 Determination of Particle Size Distribution Test (Sieve Analysis)

300g of air dried soil that passes sieve no 5.00mm was weighed and soaked in water for 24 hours. The soil was later washed through a BS 2.0 mm test sieve nested on BS 75μm test sieve until all the fine particles were removed.

This is achieved when the water passing through sieve No 75μm was totally clear. The sample retained on the two sieves was then collected in a weighing pan and oven dried for 24 hours at 100^0C. The dried sample from the oven was weighed and recorded.

A set of BS sieve was then arranged in a descending order and poured the sample on the top sieve (ie no 5.00mm). The top sieve was covered to avoid the escape of soil grains from the top sieve during operation. The set of sieve were then mounted on mechanically sieve shaker electrically operated and it is allowed to vibrate for about 10 minutes before the machine is switched off.

The sieves were then removed one after the other and their respective weight plus retained sample (materials) were taken and recorded as shown in table 3.3. The percentage weight of the retained sample was calculated using the formula below.

$$\text{Percentage retained} = \frac{\text{weight of sample retained on sieve}}{\text{Initial weight of washed sample}} \times 100 \qquad (3.3)$$

Percentage passing = 100 – cumulative percentage retained

Table 3.3 Particle Size Distribution Test

Sieve size(mm)	Wt of sample retained (g)	%wt retained	Cumm.% retained	% Passing
5.00	0	0	0	100
3.35	2.2	0.7	0.7	99.3
2.00	24.5	8.2	8.9	91.1
1.18	26.5	8.8	17.7	82.3
0.55	12.2	4.1	21.8	78.2
0.60	8.2	2.7	24.5	75.5
0.45	5.5	1.8	26.3	73.7
0.300	8.4	2.8	29.1	70.9
0.15	30.5	10.2	39.3	60.7
0.075	18.6	6.2	45.5	54.5

3.2.1.4 Determination of Liquid Limit Test Using Cone Penetrometer Method

3.2.1.4a Liquid Limit Test

200g of laterite sample passing sieve no 425μm was weighed and poured on a glass plate. The distilled water was added to the sample and mixed thoroughly until uniform paste was achieved. About 20g of the paste was set aside for plastic limit test. The remaining sample was then put into a brass cup with a palette knife without applying much pressure on the sample. The sample is then leveled with the top edge of the cup using the spatula to give a smooth surface. The cup was positioned under the cone penetrometer with the tip of the cone just in contact with the paste surface. The dial gauge was set at zero and the cone was released through a knob to penetrate the paste. The depth of penetration was taken from the gauge and the small portion of the paste was taken for moisture content determination. The paste was emptied from the cup and put back on the glass plate. A small quantity of water was added and mixed thoroughly again and the process repeated for another four trials.

The graph of penetration against moisture content was plotted and the moisture content that correspond to 200mm penetration depth is taken as the liquid limit of the sample. The penetration depths and moisture contents readings were recorded and tabulated in the table 3.4 below.

3.2.1.4b Plastic Limit

The set aside 30g of already mixed paste during the liquid limit test was broken into smaller parts and shaped into small balls. The ball of soil should be rolled by hand on a glass plate with sufficient pressure to form a thread of 3mm diameter on crumbling/cracking. The portions of the cracked threads were placed in the moisture cans, and the weights were taken before and after oven drying for moisture content determination. The average moisture content in the plastic limit column is taken as plastic limit value in percentage.

The readings of plastic limit tests were also tabulated in the table 3.

3.2.1.4c Plasticity Index

Plasticity index is the numerical difference between the values of liquid limit and plastic limit of a soil.

Table 3.4 Liquid Limit and Plastic Limit

Trial No	1	2	3	4	5	plastic limit (PL)	
						1	2
Penetration (CM)	10.2	11.3	13.8	16.3	20.5		
weight of can (g)	24.3	16.0	18.90	19.90	18.2	21.9	21.6
weight of can + wet soil (g)	36.4	28.3	38.7	37.10	36.6	23.0	22.9
weight of can + dry soil (g)	33.6	25.4	33.90	32,60	31.7	22.8	22.70
weight of moisture (g)	2.80	2.90	4.80	4.50	4.90	0.20	0.20
weight of dry soil (g)	9.30	9.40	15.00	12.70	13.5	0.90	1.10
Moisture content (%)	30.11	30.85	32.00	35.43	36.30	22.22	18.18
Average plastic limit				20.20%			

3.2.1.5 Determination of Soil Compaction Test

3kg of air dried lateritic soil sample passing through BS sieve no 5.00mm was measured out using the weighing balance and poured on the tray. The empty mould with base plate was weighed and recorded. The water was added to the soil sample and mixed properly to give a uniform mixture without addition of river sand. This is to obtain optimum moisture content and MDD of lateritic soil to serve as a control. The moist soil was then put into the coupled mould in three equal layers, given each layer 25 blows, using 4.5kg rammer.

The blows were distributed evenly over the surface of each layer. The collar attachment was removed and the compacted soil surface was smoothen and leveled with the top of mould. The mould and compacted soil were weighed and recorded. Small quantity of compacted sample were taken from the top and bottom of the mould and put into two moisture cans for onward placement into the oven for 24 hours. The remaining compacted sample in the mould was extruded back to the tray and little quantity of water was added and mixed thoroughly again. The above processes that follows the mixing were repeated until based on wet masses, a peak value is followed by one or two slightly lesser compacted masses.

The entire process was repeated for 5, 10, 15 ...to 100% of river sand added to 3kg of lateritic soil.

The dry weights were taken after 24 hours and average moisture content were determined for each trial test. The dry densities were calculated and graph of dry density against moisture content were ploted for each percentage in consideration.

The formular used for determination of bulk density, moisture content and dry densities were given below.

$$\text{Bulk density} = \frac{\text{weight of compacted soil (g)}}{\text{Volume } (944\text{cm}^3)} \tag{3.4}$$

$$\text{Moisture content } (\%) = \frac{\text{weight of Water}}{\text{Weight of Dry Soil}} \times 100 \tag{3.5}$$

$$\text{Dry density} = \frac{\text{bulk density}}{1 + \text{moisture content}} \tag{3.6}$$

The compaction test table for 0% (Modified AASHTO) is shown below in table 3.5.

The format remains the same for other percentages of 5 to 100.

Table 3.5 Compaction Test Table for 0 % (Modified AASHTO)

Test No.	1		2		3		4		5	
Weight of mould (g)	4800		4800		4800		4800		4800	
Wt of mould + wet soil (g)	6531		6751		6870		6834		6750	
Wt of can m_1 (g)	24.7	24.7	24.1	9.7	24.4	22.1	24.1	24.9	23.3	24.8
Wt of can + wet soil (g) M_2	41.9	45.3	54.7	39.6	59.2	57.4	56.8	64.8	57.4	66.0
Wt of can +dry (g) (M_3)	40.6	43.7	51.5	36.8	55.0	53.2	52.1	59.1	51.8	59.5
Wet of moisture (g)	1.30	1.60	2.90	2.80	4.20	4.20	4.70	5.70	5.60	6.50
Wt of dry soil (g)	15.9	19.0	27.70	27.10	30.60	31.10	28.00	34.20	28.5	34.70
Moisture content (%)	8.18	8.42	10.47	10.33	13.73	13.50	16.70	16.67	19.7	18.73
Average moisture content (%)	8.30		10.40		13.62		16.73		19.19	
Dry density (g/cm^3)	1.690		1.880		1.930		1.850		1.730	

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Index Properties Test

The results for the identification and classification tests carried out on the natural lateritic soil sample as well as compaction characteristics are presented in the table below.

Table 4.1.1 Classification test result for the lateritic soil

Tests	Results
Natural moisture)	19
Percentage passing BS 2.00 (%)	91.1
Liquid limit (%)	36.82
Plastic limit (%)	20.20
Plasticity index (%)	16.62
AASHTO classification	A-6
Unified soil classification system (USCS)	CL
Maximum dry density (MDD)g/cm^3 (AASHTO)	2.085
Optimum moisture content (OMC)% (AASHTO)	12.8
Specific gravity (Gs)	2.62
Texture	Fine grain soil
Colour	Reddish brown.

From the Table 4.1.1 the soil sample has natural moisture content of 19% and specific gravity of 2.62.

Based on the results of particle size distribution and liquid limit tests, the lateritic soil sample was classified under the AASHTO classification system as A-6 soil and clay of low plasticity (CL) under unified soil classification system (USCS) respectively. From the particle size distribution curve in figure 4.1.0, the percentage passing sieve BS 2.00mm is 91.11% while in figure 4.1.1 the results shows that the liquid limit, the plastic limit and plasticity index values read as 36.820%, 20.20% and 16.62% respectively.

4.2.0 Compaction Characteristics

The summary of compaction characteristics of the mixture (lateritic soil and river sand) at AASHTO compaction energy were presented in the tables 4.1.2. While the graph of MDDs against percentage river sand for the mixture were shown in figure 4.1.2 and that of OMCs against percentage river sand were shown in figure 4.1.3.

From figure 4.1.2, it was observed that the MDD increases with increase in compacting energy (that is, Modified AASHTO). At AASHTO energy level, the MDD increases from 1.9350g/cm3 at 0% to 2.085g/cm3 at 95% river sand after which the values becomes relatively constant with further increase in river sand.

This increase is probably due to presence of cohesion less hard quartz minerals in river sand which does not decomposed at all. With increase in river sand, the fine quartz minerals gradually displaced the clay particles in the natural lateritic soil thereby increasing the density of the mixture. When the clay is fully or partially displaced by the river sand, a state of steady or uniform density is reached and this can be attributed to the higher specific gravity of river sand compared to that of clay.

The OMC however decreases with increase in river sand from 12.8% at 0% river sand to 10.7% at 85% river sand.

Table 4.1.2: Summary of MDDs and OMCs result for AASHTO

River sand %	MDD(g/cm^3)	OMC (%)
0	1.935	12.8
5	1.942	12.7
10	1.985	12.4
15	1.958	12.5
20	1.974	12.6
25	1.995	11.8
30	2.00	11.5
35	2.011	10.7
40	1.979	11.3
45	1.994	11.1
50	1.987	11.2
55	1.964	12.1
60	1.980	11.8
65	1.971	11.9
70	2..039	10.8
75	2.046	10.5
80	2.031	10.8
85	2.052	10.7
90	2.048	10.7
95	2.085	11.0
100	2.020	10.9

Table 4.1.3: Natural Moisture Content of Lateritic Soil

Can number	1	2	3
Can weight (g)	24.2	27.9	24.7
Weight Of Can + Wet Soil (g)	52.4	57.9	59.5
Weight of Can + Dry Soil (g)	47.8	53.1	53.8
Weight of Moisture (g)	4.60	4.80	5.70
Weight of Dry Soil (g)	23.60	25.20	29.10
Moisture Content (%)	19.49	19.05	19.59
Average M.C (%)		19%	

Table 4.1.4: Specific Gravity of Lateritic Soil

Trial No	1	2	3
Weight of empty bottle (g)	97.5	114.2	126.7
Weight Of bottle + Dry Soil (g)	129.9	148.5	164.7
Weight of bottle + soil + water (g)	376.5	394.5	410.6
Weight of bottle + water (g)	356.6	373.2	387.0
Specific Gravity (Gs)	2.59	2.64	2.64
Average specific gravity (Gs)		2.62	

Table 4.1.5: Specific Gravity of River Sand

Trial No	1	2
Weight of empty bottle (g)	114.4	97.7
Weight Of bottle + Dry Soil (g)	157.6	138.1
Weight of bottle + soil + water (g)	389.6	381.8
Weight of bottle + water (g)	362.7	356.5
Specific Gravity (Gs)	2.65	2.68
Average specific gravity (AGs)	2.67	

Table 4.1.6: Grain Size Analysis (Laterite)

Project : Kebbi		
Test Location :		
Sample no. : Sample A	**Initial Sample mass :** 300 g	**Date :** 03/03/2012
Sample Description :		

Sieve size (mm)	Mass retained (g)	% Retained	% Passing
5.000	0	0.00	100.00
3.350	2.2	0.73	99.27
2.000	24.5	8.17	91.10
1.180	26.5	8.83	82.27
0.850	12.2	4.07	78.20
0.600	8.2	2.73	75.47
0.425	5.5	1.83	73.63
0.300	8.4	2.80	70.83
0.150	30.5	10.17	60.67
0.075	18.6	6.20	54.47
	Hydrometer Analysis		

Fig.4.1.0 Graph of sieve analysis for laterite

Table 4.1.7: Sieve Analysis result (River Sand)

Project : Kebbi			
Test Location : River sand			
Sample no. : Sample B	**Initial Sample mass :** 300	g	**Date :** 03/03/2012
Sample Description :			

Sieve size (mm)	Mass retained (g)	% Retained	% Passing
5.000	0	0.00	100.00
3.350	1	0.33	99.67
2.000	5.9	1.97	97.70
1.180	24.5	8.17	89.53
0.850	27.8	9.27	80.27
0.600	43.5	14.50	65.77
0.425	47	15.67	50.10
0.300	44.9	14.97	35.13
0.150	74.9	24.97	10.17
0.075	17.4	5.80	4.37
	Hydrometer Analysis		

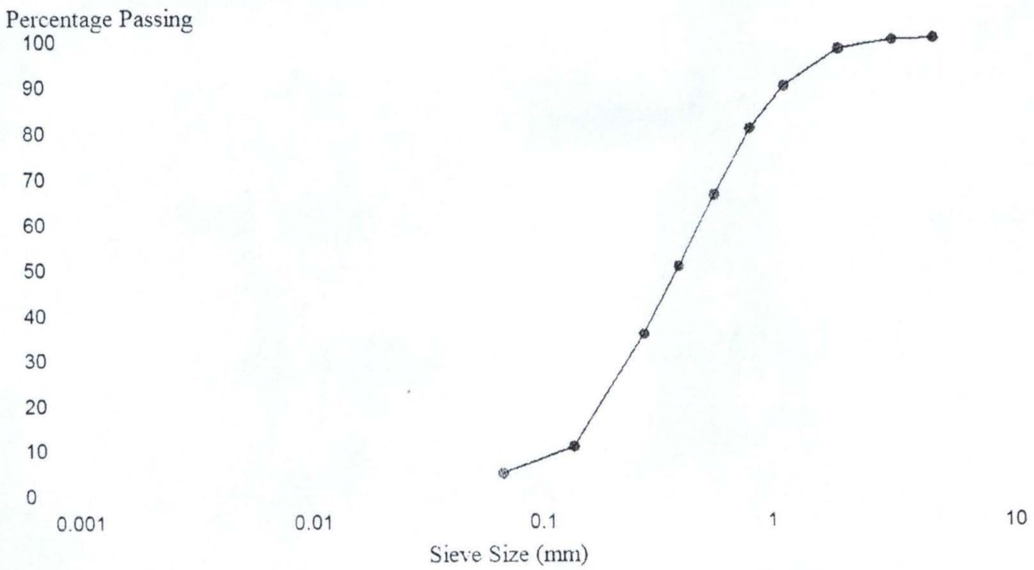
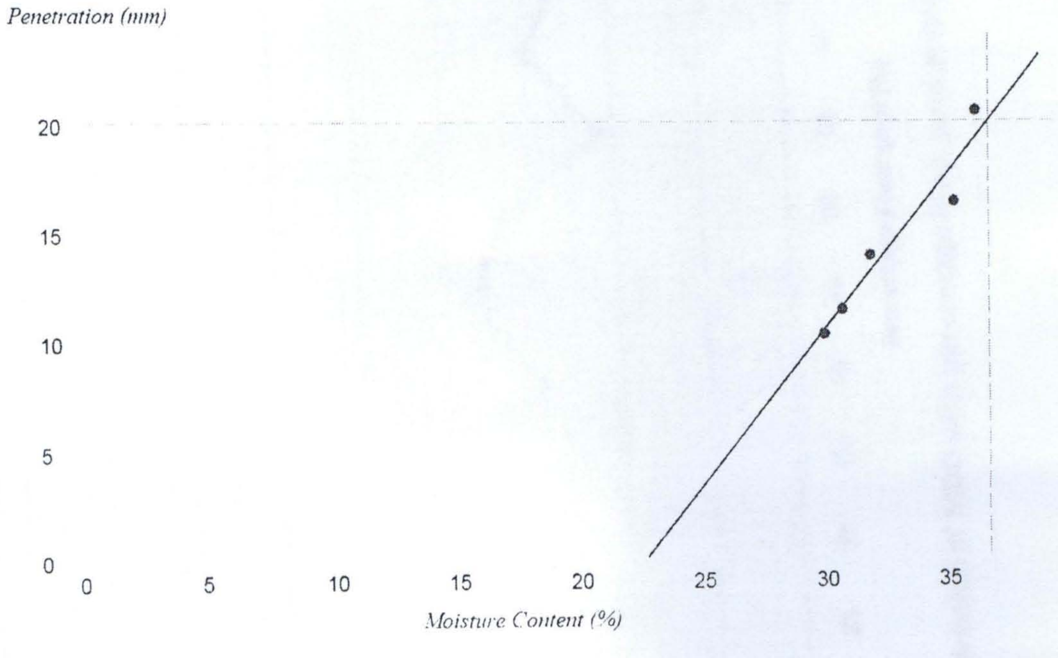


Fig.4.1.0a Graph of sieve analysis for river sand

Table 4.1.8: Liquid limit determination

Project : Liquid limit for Natural laterite (Abubakar thesis)		
Test Location : Retrail		
Sample no. :	**Depth of sample :**	**Date :**
Sample Description :		

	LIQUID LIMIT					PLASTIC LIMIT	
Can Number	1	2	3	4	5	1	2
Penetration	10.2	11.3	13.8	16.3	20.5		
Can Weight	24.3	16.0	18.9	19.9	18.2	21.9	21.6
Weight of Can + Wet Soil	36.4	28.3	38.7	37.1	36.6	23.0	22.9
Weight of Can + Dry Soil	33.6	25.4	33.9	32.6	31.7	22.8	22.7
Weight of Moisture	2.80	2.90	4.80	4.50	4.90	0.20	0.20
Weight of Dry Soil	9.30	9.40	15.00	12.70	13.50	0.90	1.10
Moisture Content	30.11	30.85	32.00	35.43	36.30	22.22	18.18
Liquid Limit	36.82 %		Average Plastic Limit :			20.20 %	



Test executed by:

Figure 4.1.1: Graph of penetration against moisture content

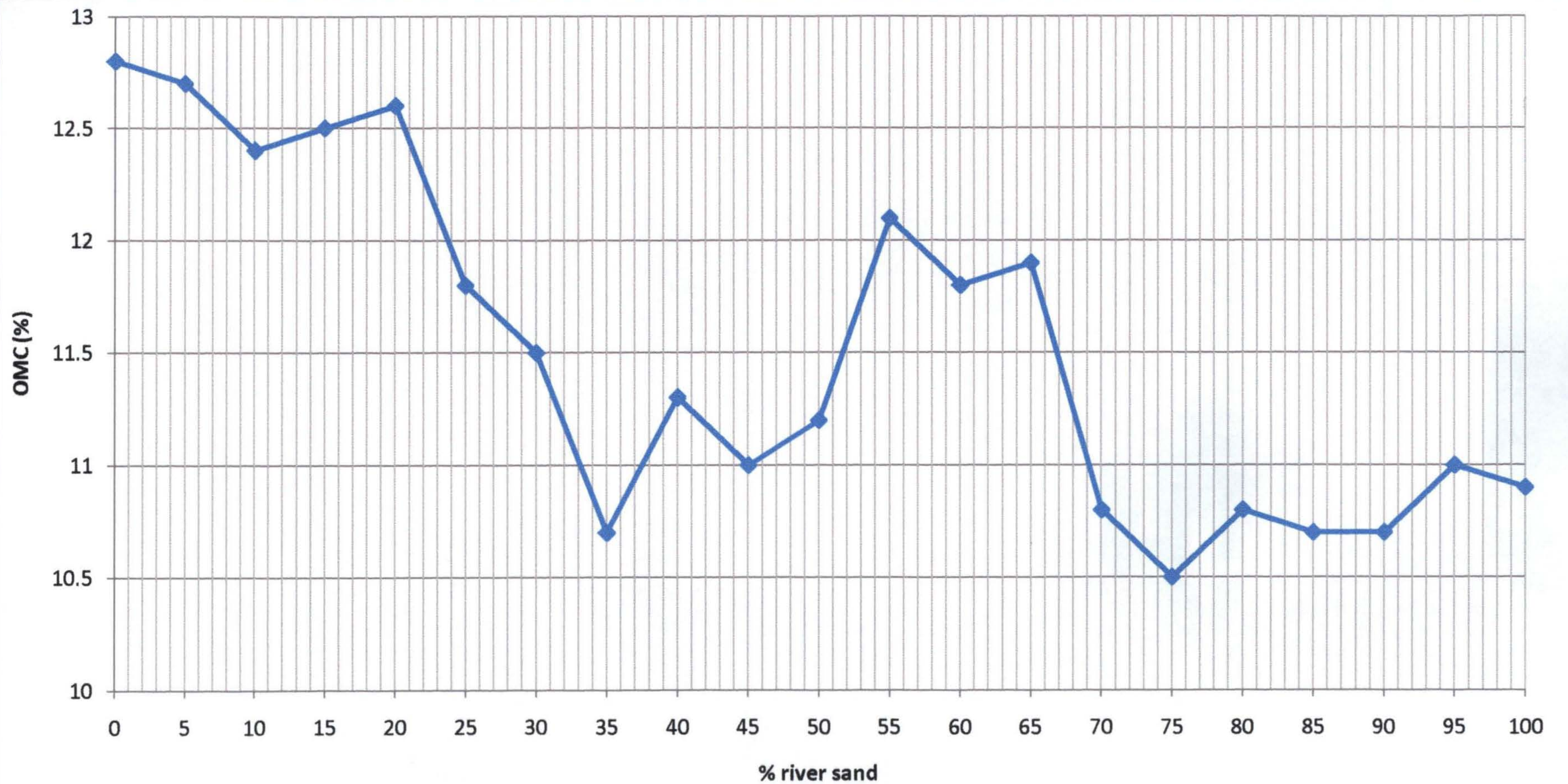


Fig.4.1.3 Variation of OMC with % riversand at BSH

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the results of the investigation carried out, the natural lateritic soil is classified under A-6 based on AASHTO classification system and clay of low plasticity (CL) under unified soil classification system (USCS).

The maximum dry density of the mixture increases while the optimum moisture content decreases with increase in river sand percentage. The MDD increases from 0% at 1.935g/cm^3 to 95% at 2.085g/cm^3. The percentage increase in MDD is 7.2% and becomes steady as from 70% to 100% river sand mixture, while the OMC decreases from 12.8% at 0% river sand to 10.7% at 85% river sand. The percentage decrease in OMC is 23.64%.

5.2 Recommendations

To ascertain the strength of the mixture for its engineering performance, it is recommended that further research work should be carried out on this topic with more emphasis on unconfined compressive strength, shear strength, California bearing ratio (CBR) test, atterberg limit test and sieve analysis tests on various percentages of the mixture.

REFERENCES

AASHTO (1986). Standard specification for transportation materials of sampling, 14th edition, Washington D.C.

Alam Sighn (2002). Soil Engineering in theory and in practice volume 1,4th edition, CBS publishers, New Delhi PP 1-3.

B.S 1377 (1990).Methods of soil test for Civil Engineering purposes. British standard institute, India. PP13-26 and 83.

Buchanan F. (1807). Journey from madras through the countries of Masore, Camara and Malabar East Indian Company, London. PP 433-560

Bowles Joseph E (1978), Engineering properties of soil and their measurements, second edition, PP 189-192.

Gidigasu, MD (1976) "Laterite soil engineering" pedogenesis and Engendering Principles, Elsevier Scientific publishing company, Amsterdam.

Lambe, W.T. (1951). Soil Testing for Engineering, John Wiley and sons, New York Toronto .PP 15-74.

Lambe, T and Whitman, R.V. (1979). Soil Mechanics, S.I. Version, U.S.A PP 7-17.

T.U. Ramamurthy and T.G. Sitharam (2005). Geotechnical Engineering, 1st edition, S. Chad and company limited, New Delhi. PP 1-3, 165-167.

Terzaghi, K. and Ralph B.P. (1927). Soil mechanics in Engineering, John Wiley and sons Inc. 2nd Edition, U.S.A. PP 20-21

Valentine O. (1983). Compressed Earth bricks masonry, Centre of earth construction Technology (CECTECH) Jos PP 7-20.

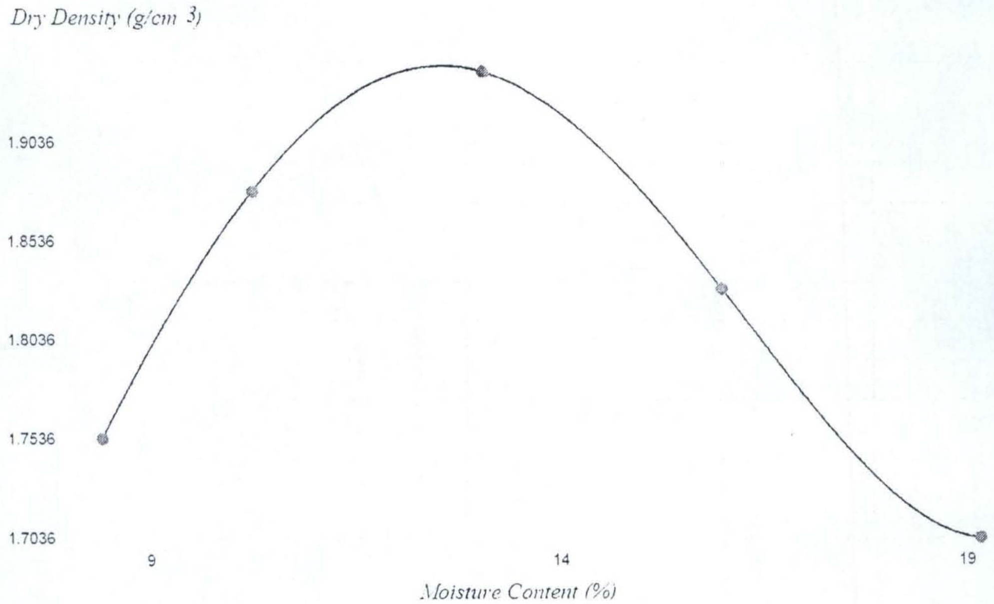
APPENDIX

Appendix A2

Table A2 Compaction test result for 5% river sand (BSH)

Project : Laterite/riversand mixture (5%)			
Test Location : Abubakar thesis			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6627		6788		6902		6836		6749	
Weight of Wet Soil (g)	1,797.00		1,958.00		2,072.00		2,006.00		1,919.00	
Wet Density (g/cm3)	1.90		2.07		2.19		2.13		2.03	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	9.7	9.9	10.5	9.8	24.8	10.0	24.7	24.6	23.5	24.9
Weight of Can + Wet Soil (g)	28.8	24.3	33.2	34.0	69.8	41.5	59.5	66.0	56.4	64.2
Weight of Can + Dry Soil (g)	27.4	23.1	31.1	31.7	64.6	37.8	54.7	60.2	51.1	57.8
Weight of Water (g)	1.40	1.20	2.10	2.30	5.20	3.70	4.80	5.80	5.30	6.40
Weight of Dry Soil (g)	17.70	13.20	20.60	21.90	39.80	27.80	30.00	35.60	27.60	32.90
Moisture Content (g)	7.91	9.09	10.19	10.50	13.07	13.31	16.00	16.29	19.20	19.45
Ave. Moisture Content (g)	8.50		10.35		13.19		16.15		19.33	
Dry Density (g/cm3)	1.7545		1.8796		1.9392		1.8296		1.7036	



MDD : 1.9421 g/cm3

OMC : 12.68 %

Test executed by: ____________________

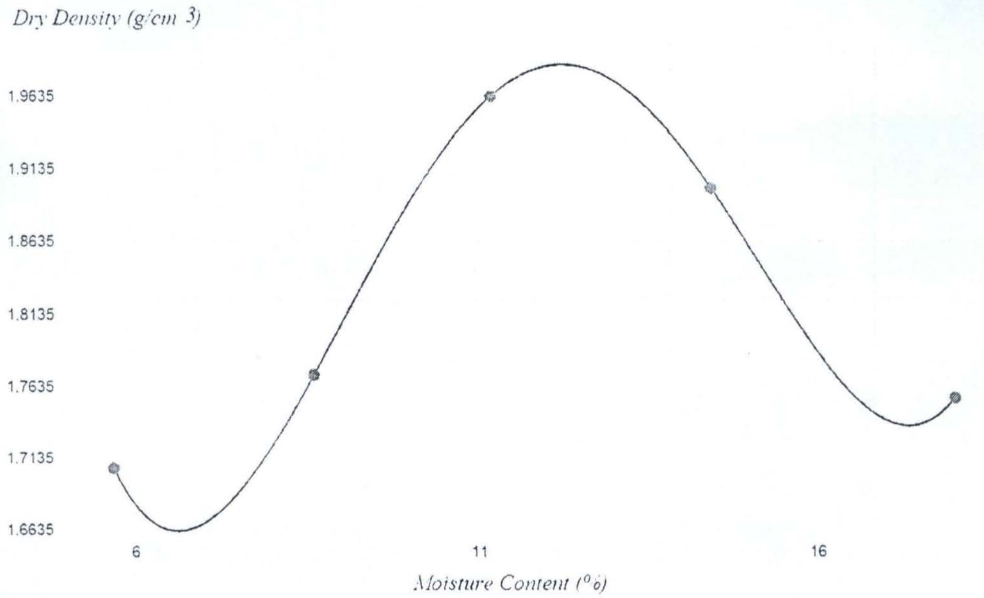
Fig.A2 Graph of Compaction for 5% river sand (BSH)

Appendix A3

Table A3 Compaction test result for 10% river sand (BSH)

Project : Laterite/riversand mixture (10%)			
Test Location : Abubakar thesis			
Sample no. :	**Volume of Mold :** 944 cm^3		**Date :**
Sample Description :			

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6535		6649		6894		6886		6790	
Weight of Wet Soil (g)	1,705.00		1,819.00		2,064.00		2,056.00		1,960.00	
Wet Density (g/cm3)	1.81		1.93		2.19		2.18		2.08	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	24.7	22.7	22.2	23.3	23.1	25.0	23.3	23.4	23.3	24.7
Weight of Can + Wet Soil (g)	45.5	45.7	47.9	48.7	49.0	52.2	54.8	53.1	60.3	64.3
Weight of Can + Dry Soil (g)	44.4	44.4	45.9	46.6	46.2	49.6	50.8	49.3	54.6	58.2
Weight of Water (g)	1.10	1.30	2.00	2.10	2.80	2.60	4.00	3.80	5.70	6.10
Weight of Dry Soil (g)	19.70	21.70	23.70	23.30	23.10	24.60	27.50	25.90	31.30	33.50
Moisture Content (g)	5.58	5.99	8.44	9.01	12.12	10.57	14.55	14.67	18.21	18.21
Ave. Moisture Content (g)	5.79		8.73		11.35		14.61		18.21	
Dry Density (g/cm3)	1.7073		1.7723		1.9637		1.9004		1.7564	



MDD : 1.9850 g/cm3

OMC : 12.40 %

Test executed by: ____________

Fig.A3 Graph of Compaction for 10% river sand (BSH)

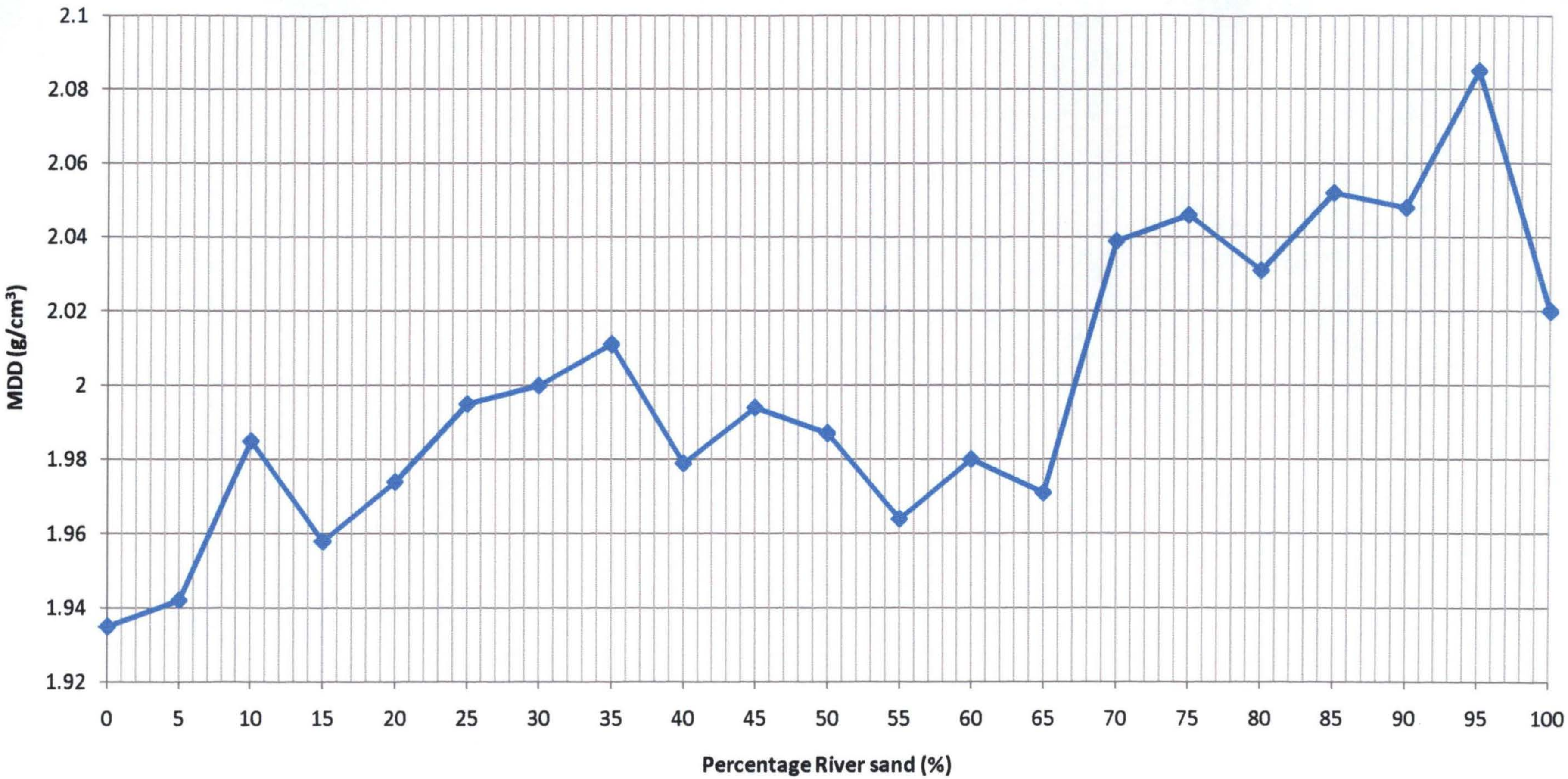


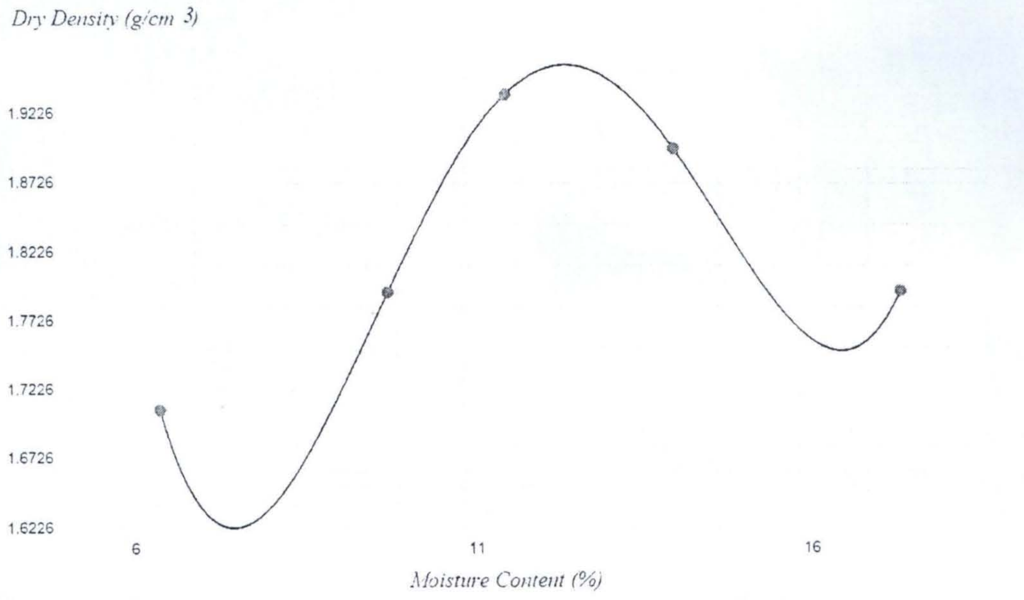
Fig 4.1.2 **Variation of MDD with percentage River sand at BSH**

Appendix A4

Table A4 Compaction test result for 15% river sand (BSH)

Project : Laterite/riversand mixture (15%)	
Test Location : Abubakar thesis	
Sample no. :	**Volume of Mold :** 944 cm3 **Date :**
Sample Description :	

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6517		6660		6840		6844		6790	
Weight of Wet Soil (g)	1,717.00		1,860.00		2,040.00		2,044.00		1,990.00	
Wet Density (g/cm3)	1.82		1.97		2.16		2.17		2.11	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.3	23.6	23.8	24.7	24.5	23.3	23.5	25.0	24.9	24.8
Weight of Can + Wet Soil (g)	49.6	40.6	52.8	47.0	50.7	50.0	64.6	61.4	63.2	65.1
Weight of Can + Dry Soil (g)	48.1	39.5	50.2	45.0	48.0	47.2	59.4	57.0	57.6	59.0
Weight of Water (g)	1.50	1.10	2.60	2.00	2.70	2.80	5.20	4.40	5.60	6.10
Weight of Dry Soil (g)	24.80	15.90	26.40	20.30	23.50	23.90	35.90	32.00	32.70	34.20
Moisture Content (g)	6.05	6.92	9.85	9.85	11.49	11.72	14.48	13.75	17.13	17.84
Ave. Moisture Content (g)	6.48		9.85		11.60		14.12		17.48	
Dry Density (g/cm3)	1.7081		1.7937		1.9364		1.8974		1.7944	



MDD : 1.9576 g/cm3

OMC : 12.50 %

Test executed by: ____________________

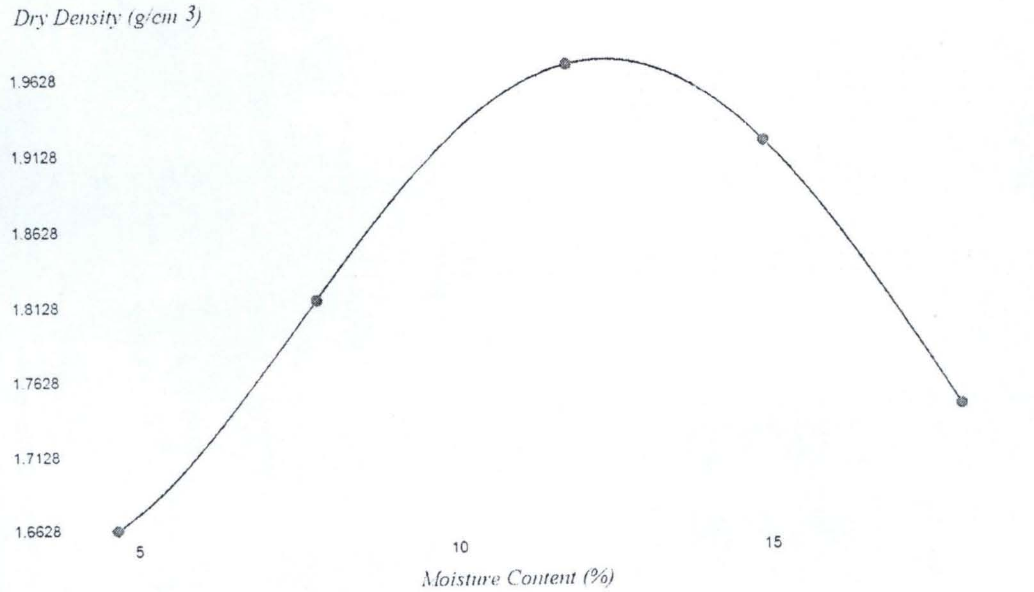
Fig.A4 Graph of Compaction for 10% river sand (BSH)

Appendix A5

Table A5 Compaction test result for 20% river sand (BSH)

Project : Laterite/riversand mixture (20%)		
Test Location : Abubakar thesis		
Sample no. :	**Volume of Mold :** 944 cm3	**Date :**
Sample Description :		

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6445		6652		6884		6886		6744	
Weight of Wet Soil (g)	1,645.00		1,852.00		2,084.00		2,086.00		1,944.00	
Wet Density (g/cm3)	1.74		1.96		2.21		2.21		2.06	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	25.2	24.9	24.5	25.1	23.7	23.3	24.4	24.6	25.4	24.9
Weight of Can + Wet Soil (g)	56.3	50.7	44.6	64.8	67.7	61.5	57.9	71.1	72.9	61.0
Weight of Can + Dry Soil (g)	54.9	49.5	43.1	61.9	63.0	57.4	53.5	65.0	65.9	55.2
Weight of Water (g)	1.40	1.20	1.50	2.90	4.70	4.10	4.40	6.10	7.00	5.80
Weight of Dry Soil (g)	29.70	24.60	18.60	36.80	39.30	34.10	29.10	40.40	40.50	30.30
Moisture Content (g)	4.71	4.88	8.06	7.88	11.96	12.02	15.12	15.10	17.28	19.14
Ave. Moisture Content (g)	4.80		7.97		11.99		15.11		18.21	
Dry Density (g/cm3)	1.6628		1.8170		1.9712		1.9197		1.7420	



MDD : 1.9743 g/cm3

OMC : 12.58 %

Test executed by: ____________

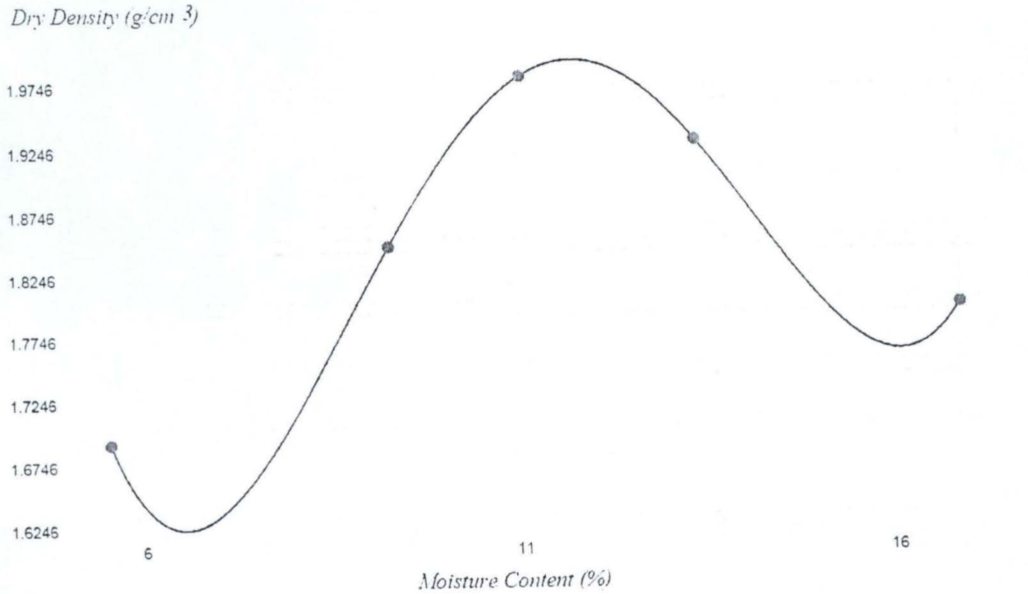
Fig.A5 Graph of Compaction for 20% river sand (BSH)

Appendix A6

Table A6 Compaction test result for 25% river sand (BSH)

Project : Laterite/riversand mixture (25%)	
Test Location : Abubakar thesis	
Sample no. :	**Volume of Mold :** 944 cm3 **Date :**
Sample Description :	

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6518		6739		6910		6900		6818	
Weight of Wet Soil (g)	1,688.00		1,909.00		2,080.00		2,070.00		1,988.00	
Wet Density (g/cm3)	1.79		2.02		2.20		2.19		2.11	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.8	23.7	23.9	23.4	23.6	23.2	23.3	24.4	25.3	24.6
Weight of Can + Wet Soil (g)	48.8	49.4	60.2	46.7	57.1	56.5	69.7	64.7	75.6	74.7
Weight of Can + Dry Soil (g)	47.4	48.1	57.1	44.7	53.7	53.2	64.2	59.9	68.3	67.4
Weight of Water (g)	1.40	1.30	3.10	2.00	3.40	3.30	5.50	4.80	7.30	7.30
Weight of Dry Soil (g)	23.60	24.40	33.20	21.30	30.10	30.00	40.90	35.50	43.00	42.80
Moisture Content (g)	5.93	5.33	9.34	9.39	11.30	11.00	13.45	13.52	16.98	17.06
Ave. Moisture Content (g)	5.63		9.36		11.15		13.48		17.02	
Dry Density (g/cm3)	1.6928		1.8491		1.9824		1.9322		1.7997	



MDD : 1.9947 g/cm3

OMC : 11.84 %

Test executed by:

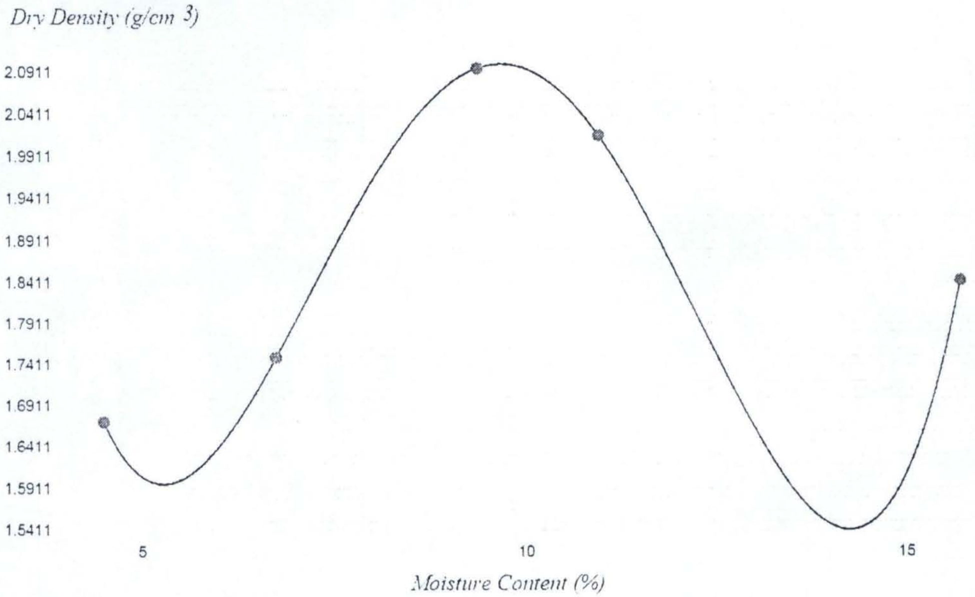
Fig.A6 Graph of Compaction for 25% river sand (BSH)

Appendix A7

Table A7 Compaction test result for 30% river sand (BSH)

Project : Laterite/riversand mixture (30%)			
Test Location : Abubakar thesis			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6481		6596		6997		6945		6847	
Weight of Wet Soil (g)	1,651.00		1,766.00		2,167.00		2,115.00		2,017.00	
Wet Density (g/cm3)	1.75		1.87		2.30		2.24		2.14	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.3	24.6	24.8	23.3	23.6	24.4	23.3	24.7	23.3	24.8
Weight of Can + Wet Soil (g)	45.7	50.0	41.7	45.0	56.1	50.5	62.4	60.6	71.8	70.5
Weight of Can + Dry Soil (g)	44.7	48.9	40.7	43.5	53.2	48.3	58.5	57.0	65.2	64.2
Weight of Water (g)	1.00	1.10	1.00	1.50	2.90	2.20	3.90	3.60	6.60	6.30
Weight of Dry Soil (g)	21.40	24.30	15.90	20.20	29.60	23.90	35.20	32.30	41.90	39.40
Moisture Content (g)	4.67	4.53	6.29	7.43	9.80	9.21	11.08	11.15	15.75	15.99
Ave. Moisture Content (g)	4.60		6.86		9.50		11.11		15.87	
Dry Density (g/cm3)	1.6720		1.7507		2.0964		2.0164		1.8440	



MDD : 2.1015 g/cm3

OMC : 9.81 %

Test executed by: ____________________

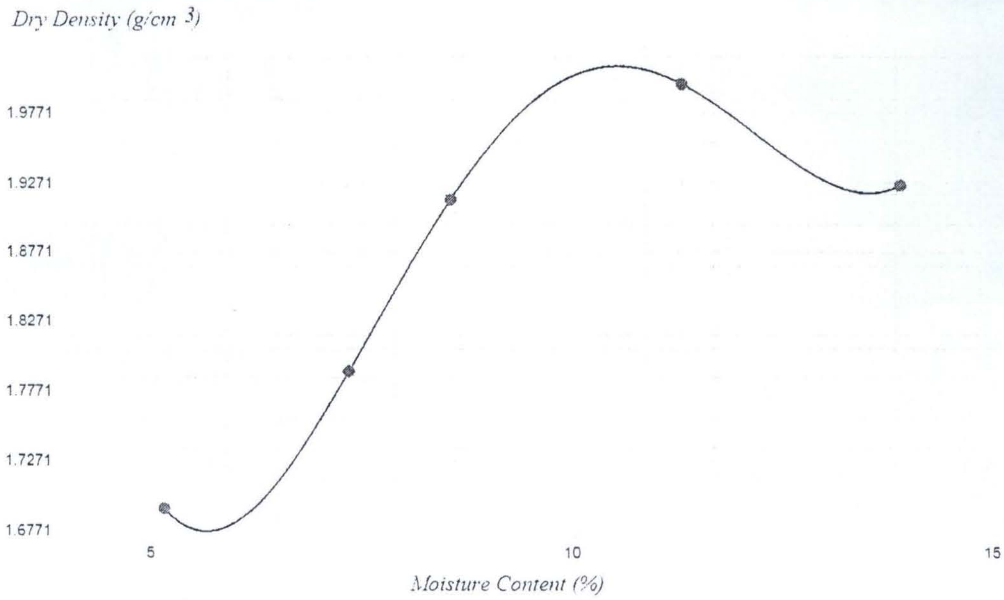
Fig.A7 Graph of Compaction for 30% river sand (BSH)

Appendix A8

Table A8 Compaction test result for 35% river sand (BSH)

Project : Laterite/riversand mixture (35%)			
Test Location : Abubakar thesis			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6483		6617		6765		6902		6873	
Weight of Wet Soil (g)	1,683.00		1,817.00		1,965.00		2,102.00		2,073.00	
Wet Density (g/cm3)	1.78		1.92		2.08		2.23		2.20	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.4	25.0	24.5	24.9	23.3	23.6	23.6	24.7	23.6	23.3
Weight of Can + Wet Soil (g)	56.0	52.5	48.4	52.8	45.7	59.0	58.3	64.0	71.1	66.8
Weight of Can + Dry Soil (g)	54.4	51.1	46.8	50.8	43.9	56.2	54.8	59.9	65.3	61.4
Weight of Water (g)	1.60	1.40	1.60	2.00	1.80	2.80	3.50	4.10	5.80	5.40
Weight of Dry Soil (g)	31.00	26.10	22.30	25.90	20.60	32.60	31.20	35.20	41.70	38.10
Moisture Content (g)	5.16	5.36	7.17	7.72	8.74	8.59	11.22	11.65	13.91	14.17
Ave. Moisture Content (g)	5.26		7.45		8.66		11.43		14.04	
Dry Density (g/cm3)	1.6937		1.7914		1.9156		1.9982		1.9256	



MDD : 2.0107 g/cm3

OMC : 10.66 %

Test executed by: ____________

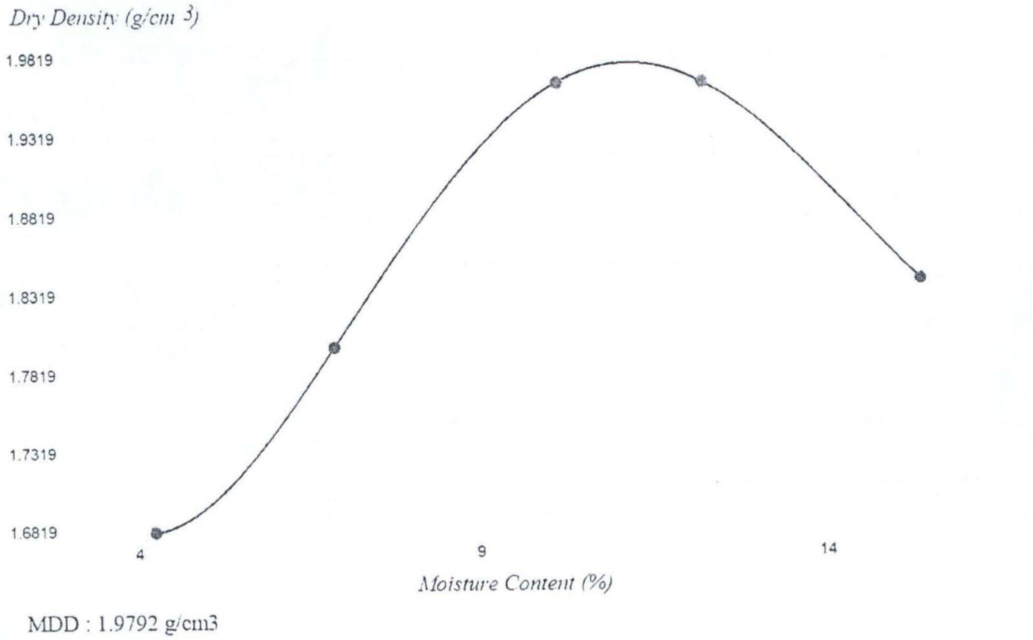
Fig.A8 Graph of Compaction for 35% river sand (BSH)

Appendix A9

Table A9 Compaction test result for 40% river sand (BSH)

Project : Laterite/riversand mixture (40%)				
Test Location : Abubakar thesis				
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**	
Sample Description :				

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6457		6617		6847		6887		6809	
Weight of Wet Soil (g)	1,657.00		1.817.00		2,047.00		2,087.00		2,009.00	
Wet Density (g/cm3)	1.76		1.92		2.17		2.21		2.13	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.9	24.5	23.3	23.8	25.0	24.8	23.5	23.8	24.5	23.3
Weight of Can + Wet Soil (g)	63.9	53.7	57.8	48.9	62.4	56.3	58.2	54.4	63.7	65.8
Weight of Can + Dry Soil (g)	62.2	52.5	55.5	47.3	59.0	53.3	54.4	51.0	58.4	60.1
Weight of Water (g)	1.70	1.20	2.30	1.60	3.40	3.00	3.80	3.40	5.30	5.70
Weight of Dry Soil (g)	38.30	28.00	32.20	23.50	34.00	28.50	30.90	27.20	33.90	36.80
Moisture Content (g)	4.44	4.29	7.14	6.81	10.00	10.53	12.30	12.50	15.63	15.49
Ave. Moisture Content (g)	4.36		6.98		10.26		12.40		15.56	
Dry Density (g/cm3)	1.6819		1.7993		1.9666		1.9669		1.8416	



MDD : 1.9792 g/cm3

OMC : 11.33 %

Test executed by: ____________

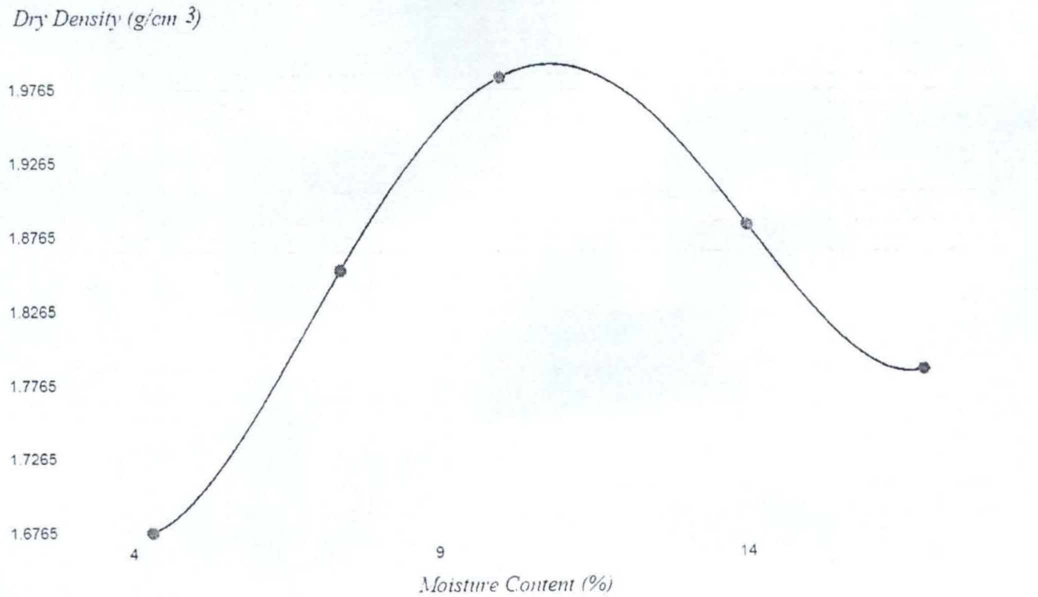
Fig.A9 Graph of Compaction for 40% river sand (BSH)

Appendix A10

Table A10 Compaction test result for 45% river sand (BSH)

Project : Laterite/riversand mixture (45%)		
Test Location : Abubakar thesis		
Sample no. :	**Volume of Mold :** 944 cm3	**Date :**
Sample Description :		

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6483		6712		6894		6862		6804	
Weight of Wet Soil (g)	1,653.00		1,882.00		2,064.00		2,032.00		1,974.00	
Wet Density (g/cm3)	1.75		1.99		2.19		2.15		2.09	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.6	22.2	24.4	24.6	22.7	25.1	23.1	24.4	23.2	24.6
Weight of Can + Wet Soil (g)	52.0	50.2	51.9	54.2	50.3	66.6	65.1	66.7	85.4	82.2
Weight of Can + Dry Soil (g)	50.8	49.0	50.0	52.1	47.8	62.7	60.0	61.3	76.2	73.9
Weight of Water (g)	1.20	1.20	1.90	2.10	2.50	3.90	5.10	5.40	9.20	8.30
Weight of Dry Soil (g)	27.20	26.80	25.60	27.50	25.10	37.60	36.90	36.90	53.00	49.30
Moisture Content (g)	4.41	4.48	7.42	7.64	9.96	10.37	13.82	14.63	17.36	16.84
Ave. Moisture Content (g)	4.44		7.53		10.17		14.23		17.10	
Dry Density (g/cm3)	1.6765		1.8541		1.9847		1.8844		1.7858	



MDD : 1.9935 g/cm3

OMC : 10.99 %

Test executed by: ______________

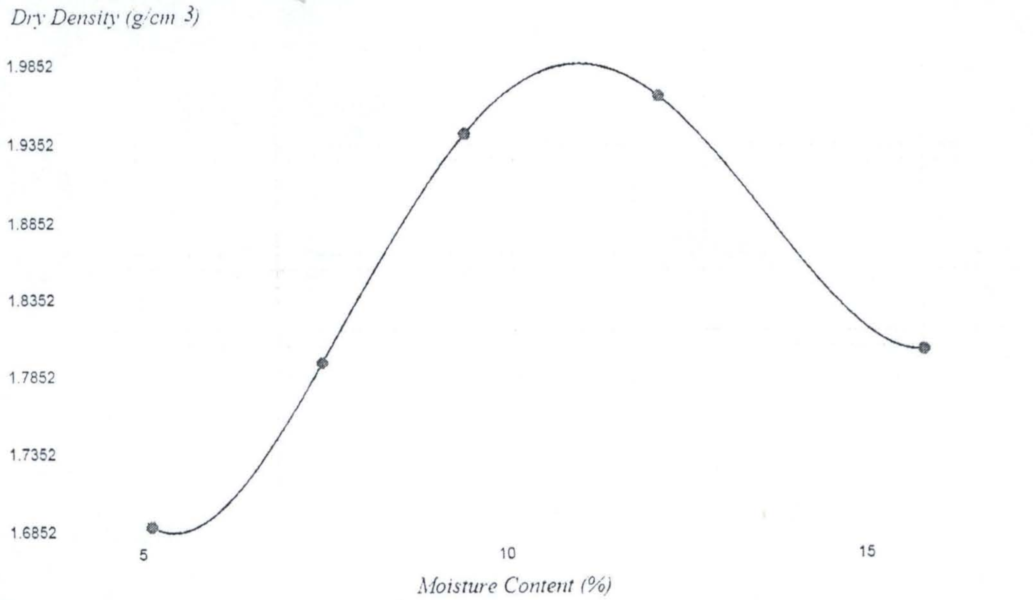
Fig.A10 Graph of Compaction for 45% river sand (BSH)

Appendix A11

Table A11 Compaction test result for 50% river sand (BSH)

Project : Laterite/riversand mixture (50%)	
Test Location : Abubakar thesis	
Sample no. :	**Volume of Mold :** 944 cm^3 **Date :**
Sample Description :	

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6508		6653		6840		6915		6804	
Weight of Wet Soil (g)	1,678.00		1,823.00		2,010.00		2,085.00		1,974.00	
Wet Density (g/cm3)	1.78		1.93		2.13		2.21		2.09	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	25.1	24.6	23.3	24.7	25.3	25.0	22.1	24.5	25.2	24.6
Weight of Can + Wet Soil (g)	46.8	47.2	53.7	52.3	50.3	60.4	58.3	65.7	68.3	71.5
Weight of Can + Dry Soil (g)	45.6	46.2	51.6	50.3	48.1	57.3	54.3	61.2	62.2	65.2
Weight of Water (g)	1.20	1.00	2.10	2.00	2.20	3.10	4.00	4.50	6.10	6.30
Weight of Dry Soil (g)	20.50	21.60	28.30	25.60	22.80	32.30	32.20	36.70	37.00	40.60
Moisture Content (g)	5.85	4.63	7.42	7.81	9.65	9.60	12.42	12.26	16.49	15.52
Ave. Moisture Content (g)	5.24		7.62		9.62		12.34		16.00	
Dry Density (g/cm3)	1.6890		1.7945		1.9423		1.9660		1.8026	



MDD : 1.9868 g/cm3

OMC : 11.23 %

Test executed by: ____________

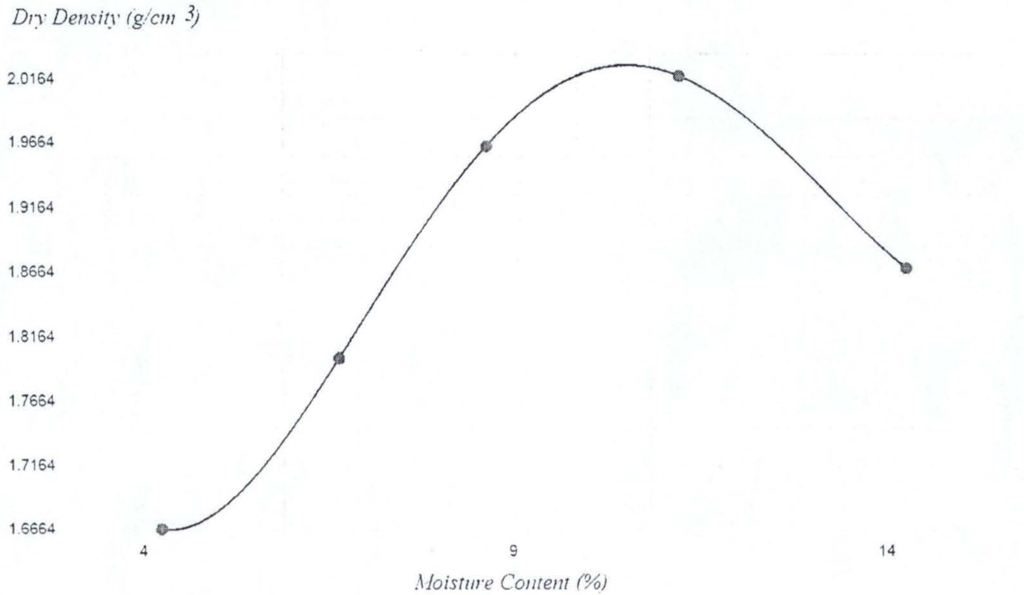
Fig.A11 Graph of Compaction for 50% river sand (BSH)

Appendix A12

Table A12 Compaction test result for 55% river sand (BSH)

Project : Laterite / river sand BSH			
Test Location : 55%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6442		6614		6817		6923		6820	
Weight of Wet Soil (g)	1,642.00		1,814.00		2,017.00		2,123.00		2,020.00	
Wet Density (g/cm3)	1.74		1.92		2.14		2.25		2.14	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.8	24.8	24.7	24.7	10.0	9.7	9.8	9.8	10.0	10.4
Weight of Can + Wet Soil (g)	59.1	56.5	63.4	55.4	48.6	45.6	50.6	54.1	66.1	64.4
Weight of Can + Dry Soil (g)	57.6	55.2	60.9	53.5	45.5	42.7	46.4	49.6	59.0	57.6
Weight of Water (g)	1.50	1.30	2.50	1.90	3.10	2.90	4.20	4.50	7.10	6.80
Weight of Dry Soil (g)	33.80	30.40	36.20	28.80	35.50	33.00	36.60	39.80	49.00	47.20
Moisture Content (g)	4.44	4.28	6.91	6.60	8.73	8.79	11.48	11.31	14.49	14.41
Ave. Moisture Content (g)	4.36		6.75		8.76		11.39		14.45	
Dry Density (g/cm3)	1.6668		1.8001		1.9646		2.0190		1.8697	



MDD : 2.0273 g/cm3

OMC : 10.68 %

Test executed by: ____________________

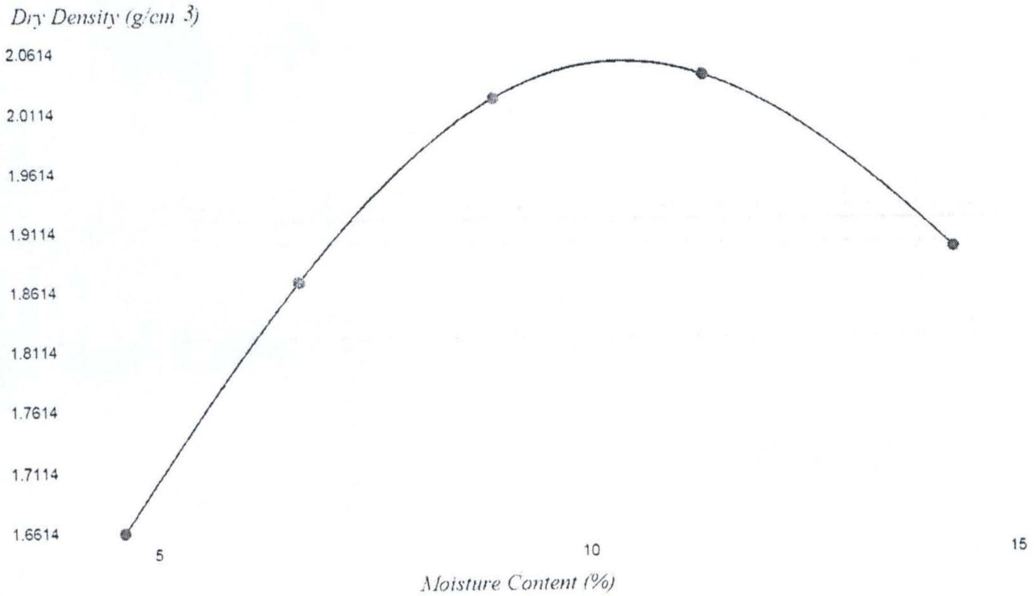
Fig.A12 Graph of Compaction for 55% river sand (BSH)

Appendix A13

Table A13 Compaction test result for 60% river sand (BSH)

Project : Laterite / river sand BSH			
Test Location : 60%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6442		6684		6883		6950		6848	
Weight of Wet Soil (g)	1,642.00		1,884.00		2,083.00		2,150.00		2,048.00	
Wet Density (g/cm3)	1.74		2.00		2.21		2.28		2.17	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.9	25.0	24.8	24.6	23.1	24.6	24.7	24.3	6.6	10.0
Weight of Can + Wet Soil (g)	57.5	58.3	58.6	49.0	55.8	60.5	57.0	66.4	69.4	75.0
Weight of Can + Dry Soil (g)	55.9	56.9	56.4	47.5	53.1	57.5	53.7	62.0	61.3	67.0
Weight of Water (g)	1.60	1.40	2.20	1.50	2.70	3.00	3.30	4.40	8.10	8.00
Weight of Dry Soil (g)	32.00	31.90	31.60	22.90	30.00	32.90	29.00	37.70	54.70	57.00
Moisture Content (g)	5.00	4.39	6.96	6.55	9.00	9.12	11.38	11.67	14.81	14.04
Ave. Moisture Content (g)	4.69		6.76		9.06		11.53		14.42	
Dry Density (g/cm3)	1.6614		1.8695		2.0233		2.0422		1.8961	



MDD : 2.0535 g/cm3

OMC : 10.58 %

Test executed by: ____________________

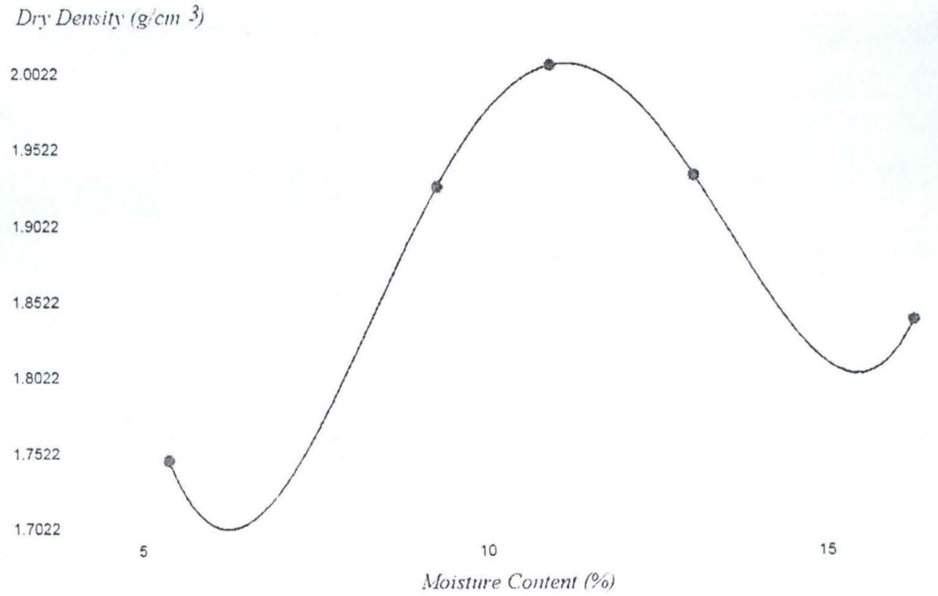
Fig.A13 Graph of Compaction for 60% river sand (BSH)

Appendix A14

Table A14 Compaction test result for 65% river sand (BSH)

Project : Laterite / river sand BSH	
Test Location : 65%	
Sample no. :	**Volume of Mold :** 944 cm^3 **Date :**
Sample Description :	

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6571		6822		6937		6900		6854	
Weight of Wet Soil (g)	1,741.00		1,992.00		2,107.00		2,070.00		2,024.00	
Wet Density (g/cm3)	1.84		2.11		2.23		2.19		2.14	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.5	25.2	24.6	23.8	24.8	24.8	24.8	24.5	26.0	25.1
Weight of Can + Wet Soil (g)	54.2	50.5	65.5	50.2	53.7	56.7	57.3	59.5	70.5	69.0
Weight of Can + Dry Soil (g)	52.7	49.1	62.0	47.9	50.9	53.4	53.5	55.4	64.2	62.8
Weight of Water (g)	1.50	1.40	3.50	2.30	2.80	3.30	3.80	4.10	6.30	6.20
Weight of Dry Soil (g)	29.20	23.90	37.40	24.10	26.10	28.60	28.70	30.90	38.20	37.70
Moisture Content (g)	5.14	5.86	9.36	9.54	10.73	11.54	13.24	13.27	16.49	16.45
Ave. Moisture Content (g)	5.50		9.45		11.13		13.25		16.47	
Dry Density (g/cm3)	1.7482		1.9280		2.0084		1.9362		1.8409	



MDD : 2.0096 g/cm3

OMC : 11.36 %

Test executed by: ____________________

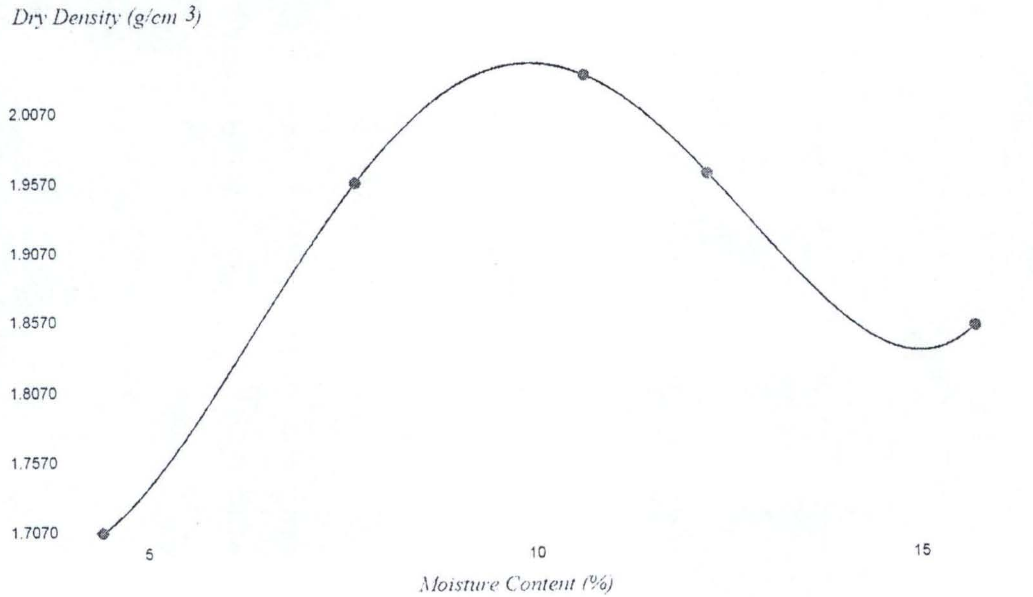
Fig.A14 Graph of Compaction for 65% river sand (BSH)

Appendix A15

Table A15 Compaction test result for 70% river sand (BSH)

Project : Laterite/Riversand (BSH)	
Test Location : 70%	
Sample no. :	**Volume of Mold :** 944 cm3 **Date :**
Sample Description :	

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6484		6792		6929		6885		6829	
Weight of Wet Soil (g)	1,684.00		1,992.00		2,129.00		2,085.00		2,029.00	
Wet Density (g/cm3)	1.78		2.11		2.26		2.21		2.15	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	25.0	24.4	24.7	25.0	22.1	24.8	24.7	24.6	24.5	24.9
Weight of Can + Wet Soil (g)	48.5	47.3	52.1	50.1	57.8	68.1	67.4	62.5	70.5	70.8
Weight of Can + Dry Soil (g)	47.5	46.3	50.1	48.3	54.3	63.9	62.7	58.3	64.4	64.3
Weight of Water (g)	1.00	1.00	2.00	1.80	3.50	4.20	4.70	4.20	6.10	6.50
Weight of Dry Soil (g)	22.50	21.90	25.40	23.30	32.20	39.10	38.00	33.70	39.90	39.40
Moisture Content (g)	4.44	4.57	7.87	7.73	10.87	10.74	12.37	12.46	15.29	16.50
Ave. Moisture Content (g)	4.51		7.80		10.81		12.42		15.89	
Dry Density (g/cm3)	1.7070		1.9575		2.0354		1.9648		1.8546	



MDD : 2.0439 g/cm3

OMC : 10.09 %

Test executed by: ____________________

Fig.A15 Graph of Compaction for 70% river sand (BSH)

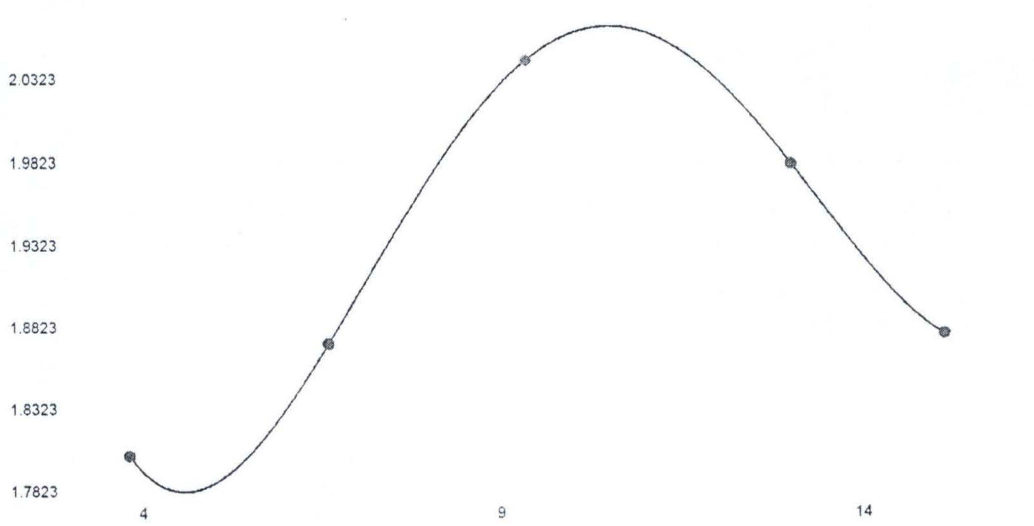
Appendix A16

Table A16 Compaction test result for 75% river sand (BSH)

Project : Laterite/Riversand (BSH)	
Test Location : 75%	
Sample no. :	**Volume of Mold :** 944 cm³ **Date :**
Sample Description :	

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6600		6716		6943		6948		6875	
Weight of Wet Soil (g)	1,770.00		1,886.00		2,113.00		2,118.00		2,045.00	
Wet Density (g/cm3)	1.88		2.00		2.24		2.24		2.17	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	24.6	23.8	24.4	25.2	24.6	23.8	26.0	24.6	23.3	23.4
Weight of Can + Wet Soil (g)	50.3	48.4	51.9	55.0	51.7	57.5	76.2	68.0	56.5	58.7
Weight of Can + Dry Soil (g)	49.3	47.5	50.2	53.1	49.5	54.4	70.4	62.9	52.1	54.0
Weight of Water (g)	1.00	0.90	1.70	1.90	2.20	3.10	5.80	5.10	4.40	4.70
Weight of Dry Soil (g)	24.70	23.70	25.80	27.90	24.90	30.60	44.40	38.30	28.80	30.60
Moisture Content (g)	4.05	3.80	6.59	6.81	8.84	10.13	13.06	13.32	15.28	15.36
Ave. Moisture Content (g)	3.92		6.70		9.48		13.19		15.32	
Dry Density (g/cm3)	1.8042		1.8724		2.0445		1.9822		1.8785	

Dry Density (g/cm 3)



Moisture Content (%)

MDD : 2.0652 g/cm3

OMC : 10.65 %

Test executed by: ____________________

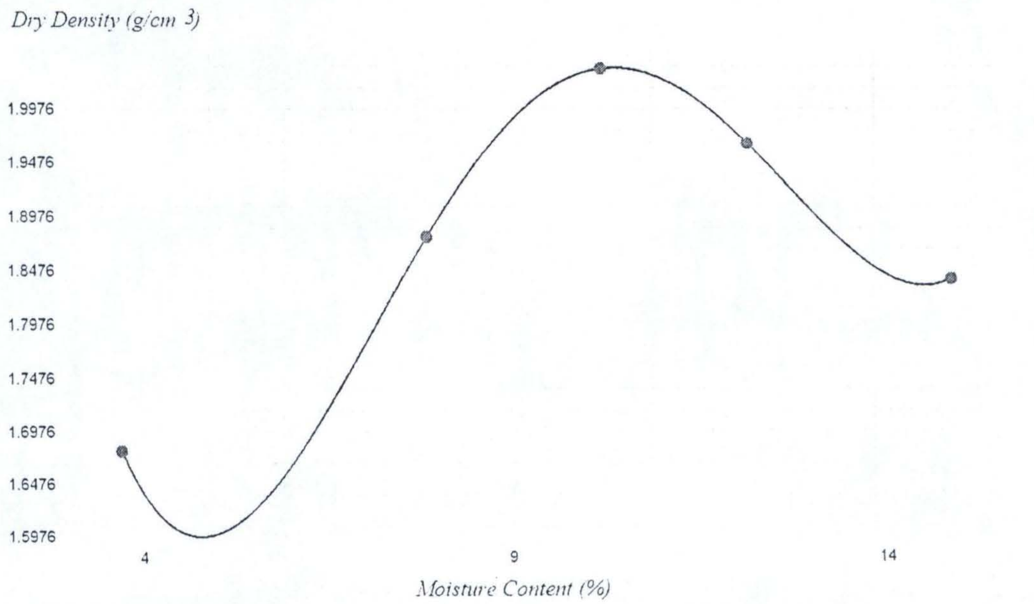
Fig.A16 Graph of Compaction for 75% river sand (BSH)

Appendix A17

Table A17 Compaction test result for 80% river sand (BSH)

Project : Laterite/Riversand (BSH)			
Test Location : 80%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6446		6715		6920		6884		6798	
Weight of Wet Soil (g)	1,646.00		1,915.00		2,120.00		2,084.00		1,998.00	
Wet Density (g/cm3)	1.74		2.03		2.25		2.21		2.12	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	24.8	23.3	23.4	23.8	22.1	25.1	24.4	24.7	24.6	24.5
Weight of Can + Wet Soil (g)	46.9	47.4	45.4	52.0	53.3	57.0	66.6	79.5	80.5	87.7
Weight of Can + Dry Soil (g)	46.1	46.5	43.8	49.9	50.4	54.0	61.9	73.6	73.4	79.2
Weight of Water (g)	0.80	0.90	1.60	2.10	2.90	3.00	4.70	5.90	7.10	8.50
Weight of Dry Soil (g)	21.30	23.20	20.40	26.10	28.30	28.90	37.50	48.90	48.80	54.70
Moisture Content (g)	3.76	3.88	7.84	8.05	10.25	10.38	12.53	12.07	14.55	15.54
Ave. Moisture Content (g)	3.82		7.94		10.31		12.30		15.04	
Dry Density (g/cm3)	1.6795		1.8793		2.0358		1.9658		1.8397	



MDD : 2.0366 g/cm3

OMC : 10.49 %

Test executed by: ____________________

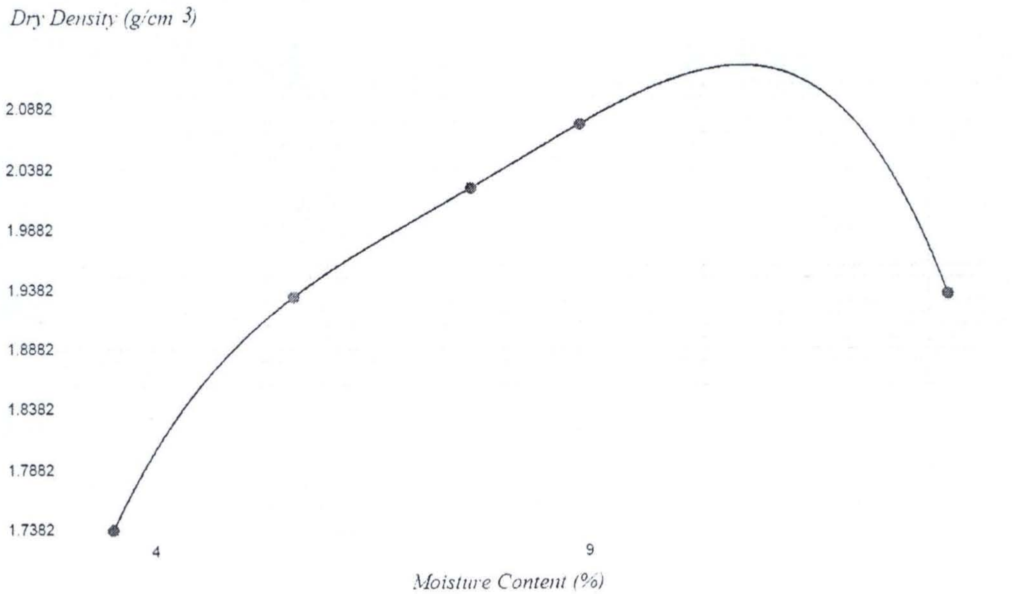
Fig.A17 Graph of Compaction for 80% river sand (BSH)

Appendix A18

Table A18 Compaction test result for 85% river sand (BSH)

Project : Laterite/Riversand (BSH)			
Test Location : 85%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6530		6758		6888		6966		6897	
Weight of Wet Soil (g)	1,700.00		1,928.00		2,058.00		2,136.00		2,067.00	
Wet Density (g/cm3)	1.80		2.04		2.18		2.26		2.19	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	25.0	23.3	23.4	23.6	24.4	24.7	24.6	24.4	23.3	24.7
Weight of Can + Wet Soil (g)	47.1	50.3	47.7	49.4	52.9	57.4	52.4	58.4	72.6	69.6
Weight of Can + Dry Soil (g)	46.3	49.4	46.5	47.9	50.9	55.0	50.1	55.6	66.8	64.4
Weight of Water (g)	0.80	0.90	1.20	1.50	2.00	2.40	2.30	2.80	5.80	5.20
Weight of Dry Soil (g)	21.30	26.10	23.10	24.30	26.50	30.30	25.50	31.20	43.50	39.70
Moisture Content (g)	3.76	3.45	5.19	6.17	7.55	7.92	9.02	8.97	13.33	13.10
Ave. Moisture Content (g)	3.60		5.68		7.73		9.00		13.22	
Dry Density (g/cm3)	1.7382		1.9325		2.0236		2.0759		1.9340	



MDD : 2.1243 g/cm3

OMC : 10.87 %

Test executed by:

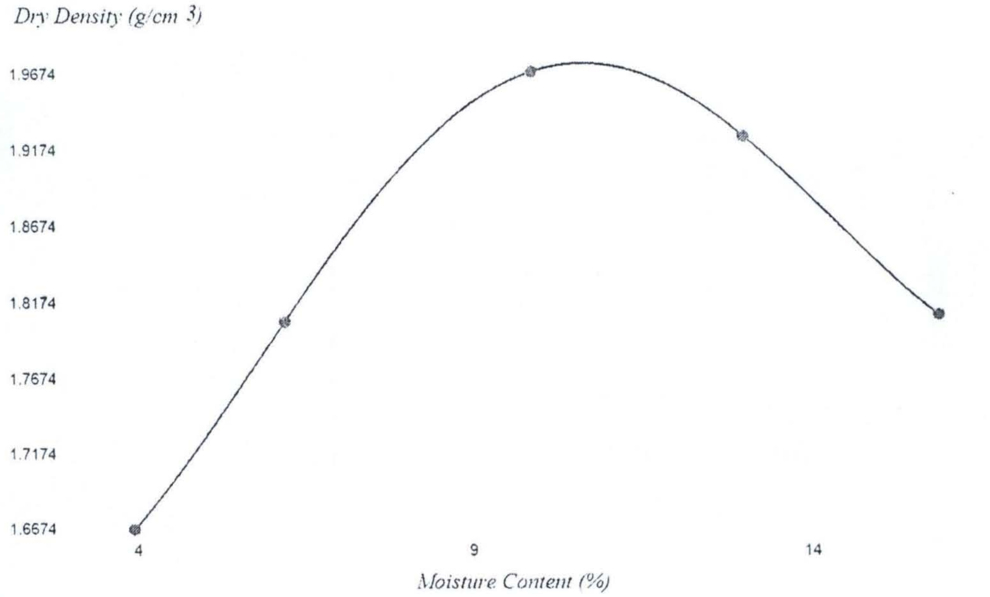
Fig.A18 Graph of Compaction for 85% river sand (BSH)

Appendix A19

Table A19 Compaction test result for 90% river sand (BSH)

Project : Laterite/Riversand (BSH)			
Test Location : 90%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6438		6612		6846		6860		6784	
Weight of Wet Soil (g)	1,638.00		1,812.00		2,046.00		2,060.00		1,984.00	
Wet Density (g/cm3)	1.74		1.92		2.17		2.18		2.10	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.5	23.5	25.1	23.4	24.8	25.0	23.9	23.7	24.7	24.8
Weight of Can + Wet Soil (g)	48.1	50.2	60.1	57.6	67.4	76.0	66.2	64.8	73.4	80.1
Weight of Can + Dry Soil (g)	47.1	49.2	57.9	55.7	63.5	71.4	61.3	60.0	66.7	72.4
Weight of Water (g)	1.00	1.00	2.20	1.90	3.90	4.60	4.90	4.80	6.70	7.70
Weight of Dry Soil (g)	23.60	25.70	32.80	32.30	38.70	46.40	37.40	36.30	42.00	47.60
Moisture Content (g)	4.24	3.89	6.71	5.88	10.08	9.91	13.10	13.22	15.95	16.18
Ave. Moisture Content (g)	4.06		6.29		10.00		13.16		16.06	
Dry Density (g/cm3)	1.6674		1.8058		1.9704		1.9284		1.8108	



MDD : 1.9760 g/cm3

OMC : 10.77 %

Test executed by: ____________

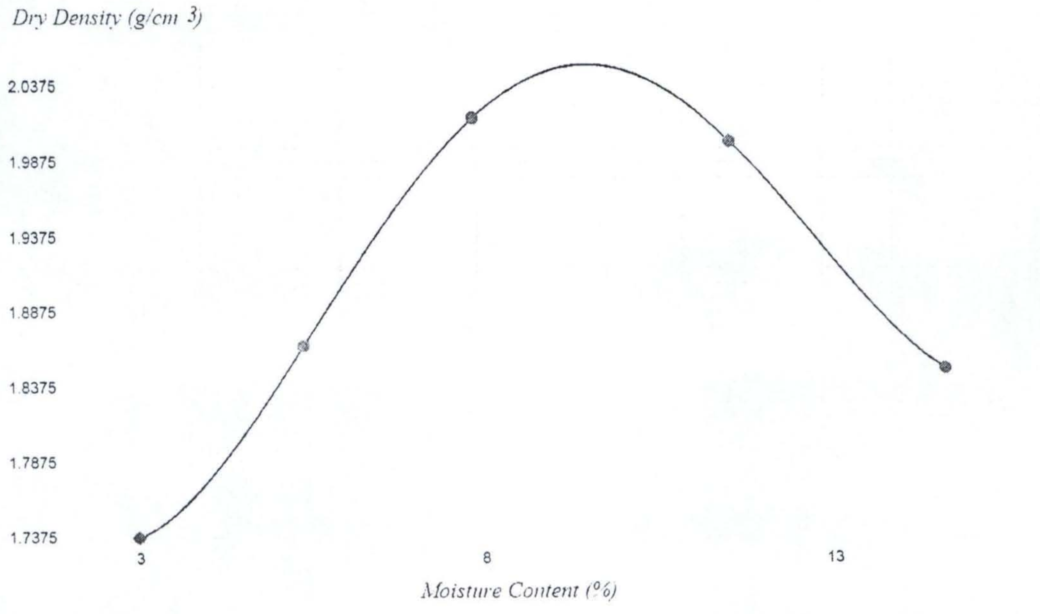
Fig.A19 Graph of Compaction for 90% river sand (BSH)

Appendix A20

Table A20 Compaction test result for 95% river sand (BSH)

Project : Laterite/Riversand (BSH)			
Test Location : 95%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4830		4830		4830		4830		4830	
Weight of Mold+Wet Soil (g)	6521		6688		6885		6940		6835	
Weight of Wet Soil (g)	1,691.00		1,858.00		2,055.00		2,110.00		2,005.00	
Wet Density (g/cm3)	1.79		1.97		2.18		2.24		2.12	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.3	24.8	23.3	23.5	23.1	25.0	23.7	29.1	24.4	23.6
Weight of Can + Wet Soil (g)	60.6	60.7	44.3	58.4	53.0	57.7	73.4	68.4	88.0	76.3
Weight of Can + Dry Soil (g)	59.5	59.6	43.2	56.6	50.8	55.3	68.2	64.3	79.7	69.6
Weight of Water (g)	1.10	1.10	1.10	1.80	2.20	2.40	5.20	4.10	8.30	6.70
Weight of Dry Soil (g)	36.20	34.80	19.90	33.10	27.70	30.30	44.50	35.20	55.30	46.00
Moisture Content (g)	3.04	3.16	5.53	5.44	7.94	7.92	11.69	11.65	15.01	14.57
Ave. Moisture Content (g)	3.10		5.48		7.93		11.67		14.79	
Dry Density (g/cm3)	1.7375		1.8659		2.0169		2.0016		1.8503	



MDD : 2.0523 g/cm3

OMC : 9.59 %

Test executed by: ________________

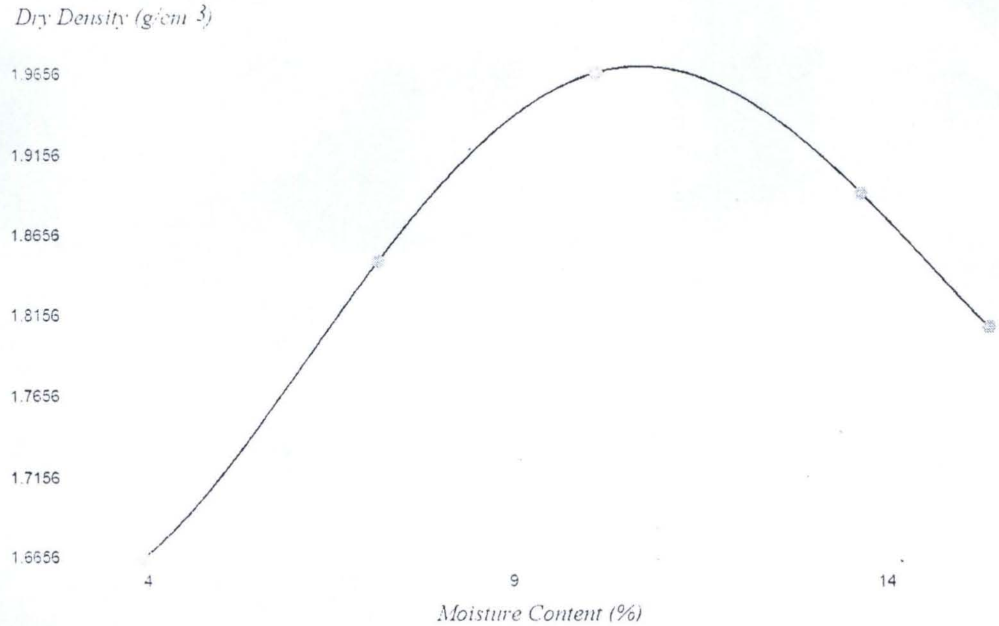
Fig.A20 Graph of Compaction for 95% river sand (BSH)

Appendix A21

Table A21 Compaction test result for 100% river sand (BSH)

Project : Laterite/Riversand (BSH)			
Test Location : 100%			
Sample no. :	**Volume of Mold :** 944	cm^3	**Date :**
Sample Description :			

Weight of Mold (g)	4800		4800		4800		4800		4800	
Weight of Mold+Wet Soil (g)	6436		6673		6847		6834		6774	
Weight of Wet Soil (g)	1,636.00		1,873.00		2,047.00		2,034.00		1,974.00	
Wet Density (g/cm3)	1.73		1.98		2.17		2.15		2.09	
Can Number	1	2	3	4	5	6	7	8	9	10
Weight of Can (g)	23.5	22.7	26.7	23.7	22.7	24.9	24.6	26.3	23.0	10.0
Weight of Can + Wet Soil (g)	60.1	50.5	59.3	57.6	75.8	78.4	73.3	65.8	82.3	61.9
Weight of Can + Dry Soil (g)	58.7	49.4	57.2	55.2	70.8	73.5	67.5	60.9	74.2	55.0
Weight of Water (g)	1.40	1.10	2.10	2.40	5.00	4.90	5.80	4.90	8.10	6.90
Weight of Dry Soil (g)	35.20	26.70	30.50	31.50	48.10	48.60	42.90	34.60	51.20	45.00
Moisture Content (g)	3.98	4.12	6.89	7.62	10.40	10.08	13.52	14.16	15.82	15.33
Ave. Moisture Content (g)	4.05		7.25		10.24		13.84		15.58	
Dry Density (g/cm3)	1.6656		1.8499		1.9670		1.8927		1.8093	



MDD : 1.9709 g/cm3

OMC : 10.85 %

Test executed by: ____________

Fig.A21 Graph of Compaction for 100% river sand (BSH)