THE RELATIVE EFFECTIVENESS OF COMMON STABILIZING AGENTS ON SHIKA LATERITIC SOIL.

BY

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DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my own research. It has not been accepted in any previous application for a higher degree. All quotations are distinquished by quotation marks and the sources of information are specifically acknowledged by means of references.

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CERTIFICATION

This thesis entitled "The relative effectiveness of common stabilizing agents on shika lateritic soil" by Malam Awaisu, Mohammed Mu'azu meets the regulations governing the award of the degree of Master of Science (Civil Engineering Construction Material) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the following.

Firstly, to the Almighty Allah for his wisdom, kindness and guidance, He bestowed on me throughout the course of my study.

Secondly, to my mother Aishatu Awaisu for her unrelenting mother's support and encouragemeat all through the period of my education up to this level.

Thirdly, to the loving memory of my late father Malam Awaisu Mohammed, who not only encouraged me, but taught me the virtues of life.

Fourthly, to my brothers and sisters so numerous to be mentioned.

Fifth and finally, to all those who strive for knowledge for the advancement of the entire humanity.

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ABSTRACT

This thesis deals with the study of the relative effectiveness of common stabilizers i.e. cement and lime and a by-product of our Steel Rolling Mills i.e. billet-scales on a natural lateritic soil from the site of Ahrradu Bello University Zaria still under construction. It involves the determination of liquid limit, plastic limit, grading analysis, maximum dry density and CBR values. A tabular and graphical representations were made. From the results of the analysis some conclusions and recommendations were made, which enhance the overall understanding of the physical and engineering behaviour of the group of soil as a highway materials.

It was found out that, with *2%* of lime, *2%* cement and 2% billet-scales the A-2-4 subgroup of soil can be upgraded to a fill material. Again with 4% lime, *2%* cement and 6% billet-scales the lateritic soil will meet the CBR requirement as a sub-base material. But only 4% of cement is required to effectively stabilize the A-2-4 sub-group of soil as a base material. And that lime is not an effective means of stabilizing silty-sand and billet-scales cannot be commented as a base material with certainty until higher percentages and/or compactive efforts are tested.

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ABBREVIATIONS

B.S	British Standard
C.B.R	California Bearing Ratio
H.R.B.	Highway Research Board
L.L.	Liquid Limit
M.D.D.	Maximum Dry Density
O.M.C.	Optimum Moisture Content
PFA	Pulverised Fuel Ash
P.I.	Plasticity Index
P.L.	Plastic Limit
P.S.I.	Pound Square Inches
R.H.A	Rice Husk Ash
T.R.R.L.	Transport and Road Research Laboratory
U.C.S	Unconfined Compression Strength
AASHTO	American Association of State Highway and Transport Officials.

NOTATIONS

C_u = Coefficient of uniformity

C_c = Coefficient of curvature

GM = Grading Modulus

D = Particle diameter

P = the fraction finer than D.

CHAPTER ONE

1.0 INTRODUCTION

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1.1 PREAMBLE

Lateritic soils have been one of the major highway and building materials in all the tropical and sub-tropical countries of the world for a long time. Fill, base and sub-base materials for most of the highways and walls of a large percentage of residential houses in rural areas have been built and will continue to be built with laterite. But in recent years, research investigations have been carried out to determine how the usefulness of lateritic soils can be improved in the Civil Engineering industry in developing countries.

The managers of construction industry in developing countries are now more aware of the need to look critically at how to improve cheap, and locally available materials such as laterite to achieve high strength for highways, airfields and lowcost houses, so as to arrest premature functional and/or structural failures. One of the possible ways is by adding different types of stabilizers to laterite in small percentages. Many types of stabilizers have been used in different parts of the world in soil stabilization for various civil engineering works, especially in highway construction. Unfortunately, some of these materials are not readily available in

some countries or some are very uneconomical to produce for local construction purposes.

The problem calls for urgent research by each developing country in order to use stabilizers that are required in small quantities or even local waste materials (e.g. Rice Husk Ash) as additives to very abundant material (lateritic soils). Such investigations will help in appreciating the utilisation of lateritic soils in highway construction work, while at the sametime help in improving the environmental conditions of developing countries as it is the case of the use of local waste materials that could otherwise have been hazardous to health

1.2 NEED FOR RESEARCH

The economic activity of developing countries is to a great extent dependent on an efficient and dependable transport system. Also the development of modes of transport (i.e. rail, water and air transport) is considerably inhibited by financial resources and topographical limitations. A well developed network of roads, it must be noted contributes to a very rapid expansion of vehicles for the movement of persons and agricultural products. Hence an adequate road network system becomes of prime importance.

The construction of roads normally covers very large

areas and spans long distances and inevitably cuts across infinite types of soils (which depend on the mineral composition of the solid particles). Therefore for a road to be constructed, large quantity of suitable civil engineering materials is required for the pavement construction or as a fill. But in most cases the required soil type might not be readily available near the proposed site, which results in locating borrow pits with large haulage distances and hence heavy transport costs. Alternatively, the problem may be solved by overlooking all other factors that are supposed to be considered when locating a route, but concentrating on soil types, which, may inevitably lead to selecting sites that offer suitable construction materials in abundance.

In all instances, nonetheless, a highway Engineer is continually faced with the problem of increasing the strength and stability of a natural soil in order to improve its load bearing properties. Hence the need for soil stabilization.

The basic ways to improve soil strength and stability are:

(i) the development of maximum practical strength by compaction.

(ii) to maintain and improve the soil strength even when soaked by water.

Broadly speaking, stabilization can be classified into mechanical stabilization and stabilization by the addition of stabilizers. However, mechanical stabilization using suitable materials can produce fills and bases of adequate strength initially, but the ingress of moisture often causes softening and weakening of the fill, base and sub-base, particularly, if excess plastic fines are present.

There is also likely to be variations in the grading and nature of soil along the right - of - way or borrow pits. These factors make uniform mechanical stabilization and compaction difficult to achieve. Again thin bituminous surfacings cannot be considered impermeable and therefore some ingress of water from the surface is to be expected which together with the inevitable wetting up from verges and also the rise in the level of water table will lead to subsequent weakening of the pavement structure. For these reasons, it is desirable to put into the fill, base and sub-base materials an additive that will to all intents and purposes overide minor variations in the soil and ensure that strength is maintained even in the presence of moisure.

Different types of stabilizers are currently in use all over the world, depending on the availability, such stabilizers include cement, lime, bitumen,

pulverised fuel ash, rice husk ash, some chemicals and more recently a study on possibility of using an industrial by - product billet scales is being undertaken. Therefore further research in the use of billet-scales as stabilizing agent will help in utmost utilization of the waste product, which will otherwise have to be transported to some designated disposal points. Hence the need for this research.

1.3 OBJECTIVE OF THE THESIS

The objectives of this thesis include the following:

1. To investigate the influence of each of cement, lime and billet scales as stabilizing agents on the Atterberg Limits, compaction characteristics and values of California bearing ratio of a selected soil sample.
2. To investigate the effect of 24 hour soaking on the performance of each soil-stabilizer mixture.
3. To investigate the possibility of using billet scales (a by - product) in particular, as a stabilizer for pavement construction and how it compares with the more conventional stabilizers in terms of strength improvement.

4. To assess the extent to which various percentages of the additives, within economical ranges, improve the characteristics of the chosen soil towards meeting the specifications for fill, sub-base and base materials respectively.

The knowledge of practical usefulness of billet-scales and lime as an alternative to cement stabilization in both highway work and other civil engineering works, such as the construction of air-fields, earthdams, lowcost houses etc, will be of great importance to the construction industry.

1.4 DESCRIPTION OF THE BASIC SOIL SAMPLE

A lateritic soil sample was collected from the site of Ahmadu Bello University Teaching Hospital still under construction at Shika, Kaduna State of Nigeria. It was a disturbed sample obtained at a depth of 1.5m below the ground surface in order to avoid vegetable matter. This area was considered because workdone by Oyegunle 1987 ón samples from the site, indicated the soil to be unsuitable in its natural form for use as sub-base and base materials.

1.5 METHODOLOGY

The basic soil sample was taken to the laboratory

and was subjected to various tests to determine its physical and engineering properties. These laboratory tests were performed in accordance with British Standards. Results of the initial tests on the sample are summarized in table 1:1. These results confirmed that the soil was unsuitable for any of fill, sub-base and base materials on account of its strength measured in terms of soaked CBR.

From the test results, the soil was confirmed as being lateritic and classified. Further laboratory work consisted of adding different percentages of the selected stabilizers to the natural lateritic soil and thoroughly mixed.

The tests listed below were then carried out:

1. Liquid limit
2. Plastic limit
3. Compaction
4. Both soaked and unsoaked CBR.

The percentages of the stabilizers used were 2, 4, 6, 8 and 10. Also soil-stabilized samples for California bearing ratio test were compacted at optimum moisture content using the British Standard Method of compaction and the soaking was for 24 hour soaking.

TABLE 1·1

PRELIMINARY TESTS RESULTS ON THE BASIC SOIL SAMPLE AND THE RECOMMENDED VALUES FROM THE SPECIFICATION

Test carried out	Result	Specification		
		subgrade	sub-base	Base
Initial moisture content content	7.33%	-	-	-
Specific gravity	2.64	≤3	≤3	≤3
Liquid limit	28.40%	≤40	≤30	≤30
Plastic limit	20.69%	—	—	—
Plasticity Index	7.51%	≤10	≤12	≤12
Optimum moisture content	16.50%	—	—	—
Maximum dry density	17.09KN/m^3	—	—	—
CBR (unsoaked)	14.94%	≥10%	≥30	≥80%
CBR (soaked)	4.63%	≥10%	25-55%	≥75%

highways, airfields, parking lots and similar facilities. For the purpose of building construction stabilization is a technique whereby natural soil is improved to serve as structural members in low-cost housing construction. Evidently, soil stabilization means different things in different circumstances.

The Chairman of the American Highway Research Board in 1938, (Ashworth, 1966) defined Soil Stabilization as:

"A stabilized fill, subgrade, road surface or road base is one that will stay put".

From whatever point one views stabilization its intended objectives are; firstly to confer stability on materials which are inherently unstable and secondly to preserve the stability of the inherently stable materials. In practice, this amounts to the water proofing of cohesive soils.

The rapid growth in road traffic, which is as a result of financial and topographical limitations which inhibits the development of other modes of transportation, i.e. rail, water and air transport has produced a demand for more bitumen-surfaced roads all over Africa. The construction of roads normally covers large areas and spans long distances and hence cuts across infinite types of soils, thereby creating difficulties in meeting the material

requirements for road construction. In most cases, the required soil type might not be readily available near the proposed site and this results in a far located borrow pits requiring large haulage distance and hence heavy transport costs. Therefore, the need of utilizing cheap local materials encountered near the proposed site cannot be overemphasised hence the advent of soil stabilization.

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2.2 TYPES OF SOIL STABILIZATION

In practice, the methods by which soils may be stabilized for highway purposes can be divided into the several broad groups which are discussed in the subsequent sub-sections.

2.2-1 Mechanical Stabilization

Basically this form of stabilization involves compaction and it is by far the most widely used method of stabilization. It relies, on the inherent properties of the soil material. If a soil cannot be made stable by compaction, then additional soils or other aggregate materials may be admixed to produce a mixture having the required stability characteristics (Road Note 31, 1977). The inherent property of the soil which is of importance is the shear strength of the soil, which is derived from both the

cohesion and the internal friction characteristics of the material. Cohesion is a property associated mainly with the clay fraction of the soil, which in-turn depends on the plasticity index. Internal friction is basically a characterisitic of sands and gravels. However, a combination of these two properties can be found in a suitably graded material.

The addition of particle sizes which are lacking in a poorly graded material produces a better graded material, which is inherently stronger and more stable than the natural soil. Good interlocking is obtained when the particles are angular with rough surfaces. The particles size distribution of a mechanically stable soil will approximate to the grading curve developed by Fuller (Ashworth, 1966). Who showed that a granular mass has a relatively high dry-density when its particle size follows the relationship represented by equation 2.1.

$$P = 100\left(\frac{d}{D}\right)^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots \quad 2.1$$

where

P = percentage passing any sieve

d = the aperture size of that sieve

D = the size of the largest particle.

However, in practice it is not necessary to use such carefully controlled distribution of particle sizes and normally a reasonably wide range of grading is used.

Mechanical stabilization using suitable material can be adequate for fills, bases and sub-bases of suitable strength initially, but the ingress of moisture often causes softening and weakening of the pavement. In particular, if excess plastic fines are present, there are also likely to be much variations in the grading and nature of soil along the line of road or at borrow pits. Again, thin bituminous surfacings cannot be considered to be impermeable and therefore some ingress of water from the surface is to be expected, which together with the inevitable wetting up from verges will lead to subsequent weakening of the pavement structure, hence leading to functional and/or structural failures, hence the main drawback of mechanical stabilization But its main popularity is based on the fact that it makes possible the optimum usage of locally available materials in highway, embankment, sub-bases, road bases and surface courses.

2.2-2 Stabilization by the Use of Additives

One other form of soil stabilization is the improvement of natural materials by the addition

of a small proportion, usually less than 10 percent of a stabilizing agent. This will, to all intents and purposes overide some minor variations in the soil and ensure that strength is maintained even in the presence of moisture.

In most cases, the presence of moisture hardens the soil-stabilizer mixture, hence stability is preserved. In general the improvements which can result from stabilization using additives include the following, Toole, 1987.

(i) increase in strength
(ii) increased resistance to the effect of water.
(iii) drying of wet soils
(iv) volumetric stability
(v) improved workability
(vi) improved durability.

The basic requirements for successful stabilization are:

1. The cost of stabilized fill, sub-base or base should compare favourably with other available forms of construction.
2. The stabilized soil must be amenable to pulverization, mixing and compaction under field conditions.
3. The stabilized material must be of adequate

strength and it should retain this strength in the presence of water.

The types of additives, which have been used for soil stabilization are:

1. Cement
2. Lime
3. Bituminous materials
4. Chemicals, other than cement and lime.

2.2-2.1 Stabilization with Cement

Cement has been successfully used to stabilize a wide range of natural gravels and soils and are usually applied in powder form. Cement has been found to stabilize virtually all soils that are practical to process, provided they are free from contamination by organic matter. However, best results are usually obtained with materials which contain a proportion of fines or clay materials. The increase in strength in cement stabilization is as a result of the reaction between soil and cement. When cement grains come into contact with water, they begin to dissolve and form a solution of calcuim hydroxide. In this calcium hydroxide, hydrated calcium silicates and calcium aluminate begin to precipitate. This compound forms masses both with each other and with other sorrounding

bodies. It is this fiber interlocking that enhances the early strength attainment in concrete. The calcium hydroxide (hydrated lime solution) is highly caustic, hence reacts with the soil particles, the attack being more active if a large surface is presented. The calcium ions attract the clay particles together tending to form aggregations. The lime also reacts relatively slowly to form further cementitious products by pozzolanic action. The resultant effect of the above three reactions is to produce hardening in a suitable soil to which cement has been added.

Active organic matter prevents the cement from hydrating, however Road Research Technical Paper No. 64, has prescribed PH test for determining whether a soil is suitable for stabilization or not. It involves determining the PH of a 10:1 soil: cement paste after one hour. It is when the PH is below 12.1 that the soil is unsuitable for stabilization. Also Road Research Laboratory has shown that when the weight of organic material exceeds approximately 2% of the soil, up to 10 percent of cement will fail to enhance the strength of the stabilised soil to acceptable level.

For assessing the strength of soil stabilized with cement or other stabilizers, most countries

authorities use the california bearing ratio (CBR) as well as unconfined compression strength (UCS) test but some use CBR test. The minimum acceptable CBR value using B.S. compaction method for stabilized bases should be equal to or greater than 80%. Whilst the minimum unconfined compression strength (UCS) is 1.72 Mpa (250lb/in^2) after 28 days curing and the liquid limit and plastic should be less than 45% and 20% respectively.

A properly designed cement stabilized soil will not soften in the presence of water and will withstand detrimental forces resulting from frost action. However, the causes of failures of cement stabilized bases can be due to:

1. The use of inappropriate strength criteria coupled, perhaps, with an unwise choice of the material being stabilized.

2. Cracking, may be a consequence of the shrinkage of hardened materials or it could be traffic induced.

   (i) Shrinkage cracking: The main cause of this form of cracking is drying shrinkage and factors which influence this include soil type, compactive effort, moisture content, rate of drying and cement content. The shrinkage cracking manifests itself by the

appearance of rectangular cracks on the surface of the cemented layer. The cracking is induced when the shrinkage stresses exceed the tensile strength of the layer. This form of cracking can be controlled, but not completely eliminated by limiting moisture loss, reducing the compation energy, by delaying the application of surface layers until shrinkage has occurred.

(ii) Traffic - Induced cracking: This type of cracking occurs through overstressing or fatique and also due to inadequate construction thickness in relation to the traffic and subgrade strength. Cemented materials are semi-brittle and if they are inadequately supported they fail. Cracking of this kind can be designed for by increasing the pavement thickness and ensuring correct balance in the strength and positioning of layer.

2.2-2.2 Stabilization with Lime

Lime can be mixed with certain soils to produce a stronger and more workable material. It is a proven methcd of improving the capabilities of clayey soils to serve as pavement materials and it can ensure considerable improvement in strength and stability in the presence of excess moisture. Cement has a relatively rapid initial

hardening effect that continues slowly with time, but that of lime is slower. This is because there is no initial action of the fibrous nature of calcium hydrates and aluminates as in cement. The only two reactions that take place with lime are as enumerated below.

(i) An immediate ion exchange (modification) in which the calcium ions are absorbed by the clay, this is followed by flocculation into groups of coarse friable particles. The effect of this ion exchange is to increase the plastic limit of the soil. It may also decrease the liquid limit but the overall effect is to reduce plasticity index and increase the bearing capacity of the soil.

(ii) Chemical hardening; a relatively slow process in which hydrated calcium silicates and aluminates are formed and the hardening continues for months. However, the hardening is accelerated by high temperatures and is partly the main reason that lime stabilisation has been utilized in tropical climates. The advantage of lime is that, the presence of organic matter in small quantities is not likely to affect the hardening as is the case with cement-treated soils. However, if carbon

dioxide (CO2) in the atmosphere combines with lime to form unreactive calcium carbonate (a reaction known as CARBONATION) it reduces the effectiveness of stabilization and in some cases retards the reaction.

2.2-2.3 Stabilization with [illegible] Bitumen

According to the Highway Research Board HRB, 1946. Bituminous soil stabilization is the name given to those methods of construction in which bituminous materials are incorporated into the soil, or soil-aggregate mixture to provide base courses.

In developing countries, the Road Engineer sometimes needs to construct a road base using cohesionless materials, bituminous stabilization is then a possible choice, particularly in an oil producing country. A number of bituminous materials including cut-back bitumens, bitumen emulsions and road tars have been used effectively as stabilizing agents. These materials increase the strength of the soil by binding the particles together and also act as waterproofing agent, preventing the absorption of water and so maintaining the strength of the stabilized material.

In general, a clean well-graded material is required in order to achieve maximum stability

content. Bitumen stabilization is generally applicable to non-plastic soils, even though they can be stabilized with cement, but with less efficiency. But 'single size' sands ($C_u < 3$, where: c_u = coefficient of uniformity) present a special problem because of their inherent lack of internal friction or cohesion. For such materials, generally a more satisfactory solution will be found by stabilizing them with bitumen than with cement.

2.2-2.4 Chemical Stabilization Other than Cement and Lime

This is either a general term for all those methods in which chemical reactions play a predominant role and would cover soil-cement, soil-lime, addition and condensation polymerisations (e.g. aniline-furfural and calcium-acrylate). Considerable interest has been shown recently in the use of chemicals for improving the strength of soil and increasing the resistance to softening by water. Among these chemicals are various resinous compounds which waterproof the soil and calcium-chloride which, because of its deliquescent nature retains moisture in soil and so assists the compaction of mechanically stabilized material in hot climates. Some of these admixtures are normally used by themselves, whilst other chemicals have been as secondary additives to the more conventional

stabilizing materials e.g. pulverised fuel ash (PFA) in conjuction with Lime. These forms of stabilization involve high cost compared with cement, lime and bitumen stabilization, but the advantage is that they can effectively deal with highly organic soils and heavy clay.

2.3 REVIEW OF RELATED WORKS

Laterite has featured for a very long time in both building and highway works in Africa. The term "laterite" was first used by Buchanam to describe ferriginous, vesicular, unstratified and porous materials with yellow ochres by its iron content occuring abundantly in Malabar in India, MD. Anisur Rahman, 1986. It was locally used for building and hence the name 'laterite' from the latin word 'later' meaning brick. Much studies have therefore been made to determine the usefulness of lateritic soils in the construction industry.

Commonly, the base course of a pavement consists of gravel or crushed stone. In most of Africa and the other developing nations, there is the shortage of stone chippings or very expensive to be produced, but an abundance of sand. Under these circumstances, it is more economical to improve the properties of the local sand or laterite than to haul gravel or crushed stone over large distances. Besides its

abundant use, interest has been shown in the material because of the frequently occuring functional and structural failures of local pavement structure of our highways and airfields. These reasons generated more investigations by different countries over the years leading to the concept of soil stabilisation. Many detailed reviews of available literature have been presented.

Epps et al, 1971, presented detailed review of available literature and summarised, that lime will react with most media, moderately fine to fine-grained soils to decrease plasticity, increase workability, reduce swell and increase strength. They also reported, that the soils that are most reactive to lime include clayey gravels, silty clays and clays. All soils classified by AASHTO as A-5, A-6 and A-7 and some soils classified as A-2-6 and A-2-7 are most readily susceptible to stabilization by lime.

They also reported the research by Robnett and Thompson M.R., 1970, which was based on experience gained with Illinois soils, have in indicated that lime may be an effective stabilizer with clay

content, as low as 7 percent. Furthermore, they reported that soils with the plasticity index as low as 8 can be satisfactorily stabilized with lime in certain instance. U.S, Armed Forces Criteria indicated that the plasticity index should be greater than 12, while representatives of the National Lime Association, indicated that a plasticity index greater than 10 should be reasonable lower limit to utilize.

In view of the suggested criteria, the authors believe that the plasticity index of the soil should have a lower limit of 10 to ensure that a reasonable degree of certainty will exist for successful stabilization with lime.

The Portland Cement Association, Mesida, 1978 indicated that all types of soils can be stabilized with cement. However, well graded granular matrix have given the best result. Limits on plasticity index have been established by the U.S. Armed Forces depending on the soil type. The plasticity index should be less than 30 for sandy and gravelly materials and less than 20 for the fine-grained soils. These limitations are necessary to ensure proper mixing of the stabilizers with the soil.

The authors also reported information developed by Oglesby C. H. and Hewes L. I. 1963, which indicated that cement should be used as a stabilizer for materials with less than 35 percent passing the No. 200 sieve and with plasticity index less than 20. However, the authors have selected a maximum plasticity index of 30 for those soils to be stabilized with cement.

Current trends indicate that stabilization with bitumen is gaining wide spread application. Requirement for aggregate grading and mixture prpperties of mixes containing bitumen have been summarized by the HRB committee on Bituminous Aggregates Bases (1970). This survey of criteria together with data published by the U.S. Armed Forces, suggested that soils that are nearly non-plastic and contain less than 18 percent passing No. 200 sieve are most suitable for bitumen stabilization.

Based on these criteria, the authors suggested a limit of 20 percent passing No. 200 sieve, a plasticity index less than 6 and the product of plasticity index and the minus No. 200 materials less than 60, have been utilized for selecting soils suitable for stabilization with bitumen. Ola, 1987 reported that Nigerian lateritic soils could be potentially stabilized by lime for highway construction

Also Ola, 1978 pointed out that Nigerian lateritic soil could be stabilized with lime, cement and bitumen, and these stabilized soils could be used for highway construction and lowcost housing. Stabilized soil is an excellent material for constructing the bases of most bituminous-surfaced roads in tropical and sub-tropical countries, Road Notes 31, 1977. He reported that most soils can be stabilized, apart from organic soils which can be identified by a rapid test. Also the adequacy of soils after stabilization with cement and lime is usually judged on the results of laboratory CBR or unconfined compressive strength tests.
A researcher ANISUR RAHMAN 1987, has pointed out that A-7-6 lateritic soil can be stabilized with 7 percent of cement to make it serve as base materials for highway construction, while 5 percent of lime can stabilize the lateritic soil for sub-base, but 18 percent of Rice Husk Ash (RHA) is required for sub-base material. He concluded that RHA can be potentially utilized as a substitute for lime and cement in order to reduce the construction cost, which may find better application in rural areas of less-developed countries. According to Grist 1965 research, where it was found out that RHA had been used as building materials in India.

Mesida 1978, has reported that, the lateritic soils in Okitipupa area of Ondo State of Nigeria need only 10-12 percent cement for stabilization to become reliable for building purposes in that area.

Oguara 1985, has reported the advantage of using cement to achieve the required strength and durability requirement for any laterite - cement block.

It has also been suggested that because lime is not always available, it may be produced on a rural industry basis in simple Kilns in regions where limestone is available TRRL, 1987. Harris et al 1983, Morais and Freeme 1977 as reported in TRRL 1987 have found out that bitumen is particularly suitable for stabilizing cohesionless sands which would otherwise pose problems if stabilized with cement.

Oyegunle, 1987, found out that, there is an increase of 1.5% in CBR value for the soaked test, which implies that for a material of 30% CBR we will require about 37% billet-scales to upgrade the material to a base material of 80% CBR. While on the other hand for the unsoaked test, for every 1% increase in billet-scales to

the material, there is a 5.55% increase in CBR value, which implies that only about 10% billet scales is requred to be added to the material in the unsoaked test to obtain a 30% CBR. But unfortunately, she hadn't completely classified the soil. However, she went to the extent of making economic comparative analysis and concluded that billet-scales stabilization is most suited in areas close to steel rolling mills.

Ingles and Metcaff, 1973, reported that Larnach has shown that the unconfined compressive strength developed by a sand stabilized with Portland Cement may be defined by Feret's strength law, given in equation 2.2.

$$S = A(C/V)^N \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 2.2$$

where

S - the unconfined compressive strength in PSI

V = Volume of pore space

A - is essentially the strength of cement, but is influenced by material and packing.

C - is the absolute volume of cement

N = Constant depending on material and geometric factors

They also reported the work done by Hutchinson, who attempted a graphical model of shear strength development and based it on triaxial tests carried

out on eleven sands. His analysis indicated that the factor N is related to the Grading Modulus (GM), by equation 2.3

$$N = 3.372 - 1.131 \log. GM \quad \ldots\ldots\ldots\ldots \quad 2.3$$

And the factor A dependent also on cement type and curing environment was related by equation 2.4.

$$A = 1.054\ N^{2.341} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 2.4$$

It is important to note that, soil stabilization involves more than a mere increase in compressive strength and shear resistance or the improvement of any other physical property of a soil. But it must supply a defence mechanism against the continually acting dynamic forces associated with the subjection of the soil system to daily as well as seasonal temperature, moisture changes and other biological activity all of which tend to destroy the integrity of the system.

CHAPTER THREE

3.0 EXPERIMENTAL PROCEDURES AND RESULTS

3.1 INTRODUCTION

The basic soil sample was collected from Ahmadu Bello University Teaching Hospital still under construction. The area was considered because previous research work done on samples from the site by Oyegunle 1987, , indicated the soil to be unsuitable in its natural form as sub-base and base material. But the researcher failed to classify the soil using any classification system, but only used billet-scales as stabilizer to improve its strength.

Therefore this experimental work is carried out not only to classify the soil using AASHTO method of classification, but also to determine the relative effectiveness of some common stabilizers and billet-scales a waste product from our Steel Rooling Mills, on the basic lateritic soil. The knowledge of the group of soil will be of great importance, because once a soil sample from anywhere is classified in its natural form and fall in the group of this basic soil sample, then the result obtained in this research work can be utilized. Also the result will help in using a waste product as a substitute to the more conventional

stabilizers (lime and cement). Since if the waste product is not utilized it has to be transported to designated disposal points.

The experimental design was determining the physical and engineering properties of the basic soil sample (control) to confirm whether the soil was suitable or unsuitable as sub-base and base material in road pavement construction, single test was carried out in each case.

When the basic soil was found to be unsuitable different percentages of the stabilizers each were added and thoroughly mixed and Atterberg, compaction and CBR tests were carried out. And the results were presented in both tabular and graphical form.

3.2 EXPERIMENTAL PROCEDURES

3.2-1 Atterberg Limit Test: Determination of the Plasticity Characteristics of the Soil-Stabilizer

The Atterberg limits test was developed in the early 1900's by a Swedish soil Scientist, A. Atterberg, who was working in the ceramic industry. He realised that at least two parameters were required to define plasticity of clays, the upper and lower limits of plasticity and he developed

simple laboratory tests to determine the limits. It was in the late 1920's that K. Terzaghi and A. Casagrande (1932b) working for the U.S. Bureau of Public Roads Standardised the atterberg limits so that they could readily be used for soil classification.

The two limits are used to fix the moisture contents at which a clayey soil passes from the solid to the plastic and from the plastic to the liquid states. These were consequently referred to as the plastic limit and liquid limit respectively. Briefly the liquid limit of soil is defined as the moisture content at which the soil is sufficiently fluid to flow a specified distance when lightly jarred 25 times in a standard apparatus. The plastic limit is defined as that moisture content at which a thread of soil can be rolled without breaking until it is only 3mm (1/8in) diameter. The numerical difference between the liquid limit and plastic limit is termed the plasticity index and indicates the magnitude of the range of the moisture content over which the soil is in a plastic condition defined by the tests.

The Atterberg limits test results with lime, scale billet and cement are as summarized in Tables 3.1 to 3.3 respectively. Also the results were graphically displayed in Fig. 1.1 - 3.3.

Table 3.1 Effects of Lime on Atterberg Limits of Lateritic Soil

Percentage	Lime	Liquid limit	Plastic limit(%)	PI (%)
0	"	28.70	20.69	7.51
2	"	41.60	27.50	14.10
4	"	41.50	28.30	13.10
6	"	43.00	23.10	19.90
8	"	45.00	28.40	16.60
10	"	43.20	24.30	18.90

Table 3.2 Effects of Billet-Scales on Atterberg Limits of Lateritic Soil

Percentage	Scale billet	Liquid limit	Plastic limit(%)	PI (%)
0	"	28.70	20.69	7.51
2	"	43.00	23.6	19.40
4	"	42.30	22.0	20.3
6	"	41.00	22.70	18.3
8	"	40.70	23.10	17.60
10	"	39.20	24.10	15.10

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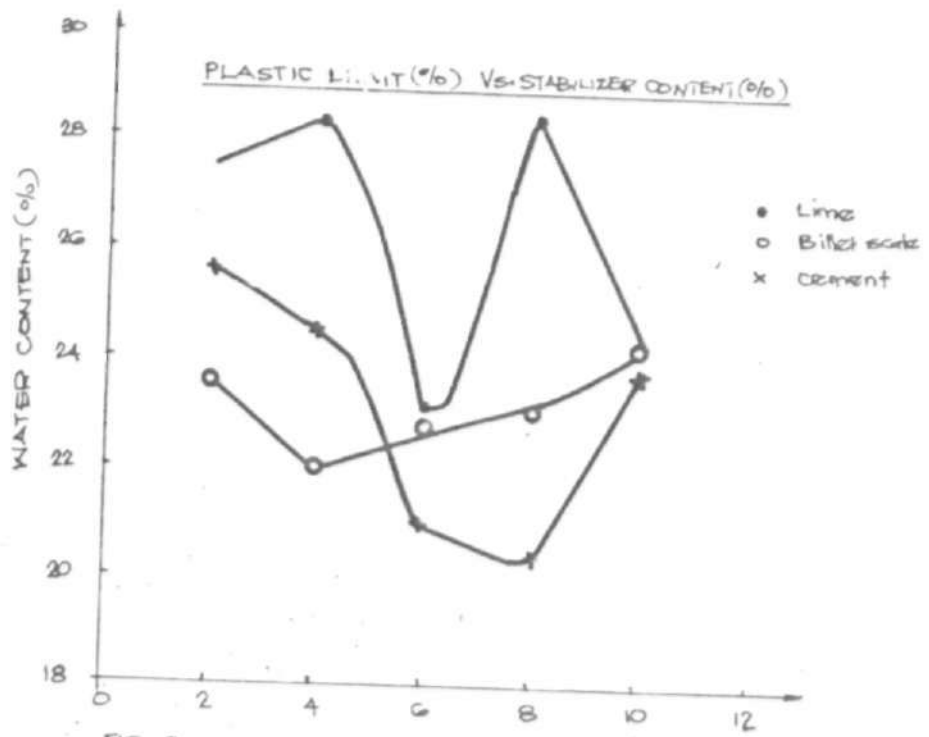

PLASTIC LIMIT (%) Vs. STABILIZER CONTENT (%)
WATER CONTENT (%)
30
28
26
24
22
20
18
0
2
4
6
8
10
12
Lime
Billet scale
Cement
STABILIZER CONTENT (%)

FIG. 3.1

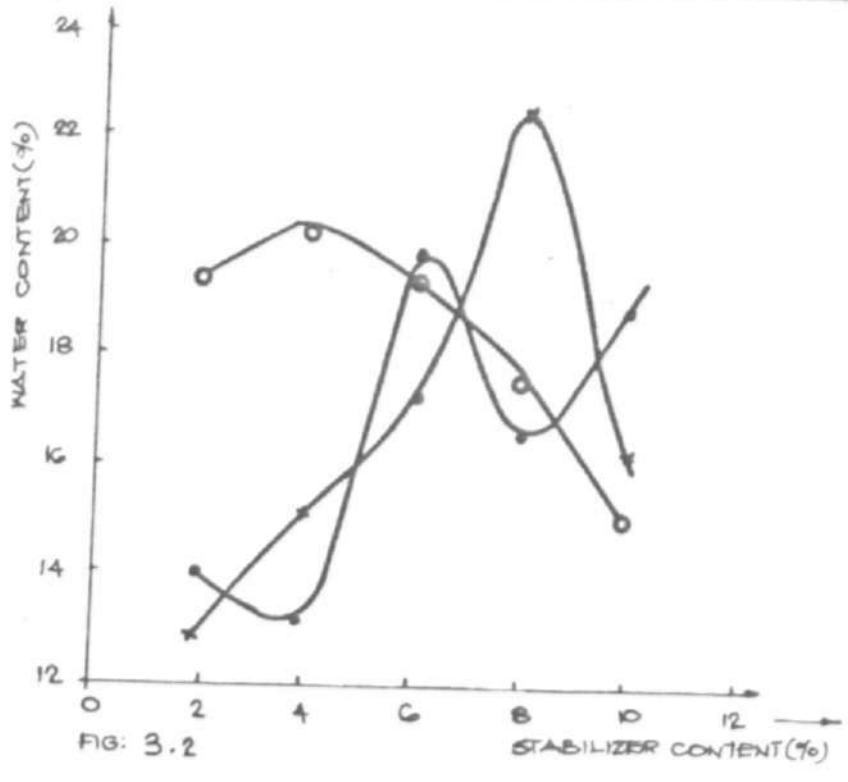

PLASTICITY INDEX Vs. STABILIZER CONTENT (%)
WATER CONTENT (%)
24
22
20
18
16
14
12
0
2
4
6
8
10
12
STABILIZER CONTENT (%)

FIG. 3.2

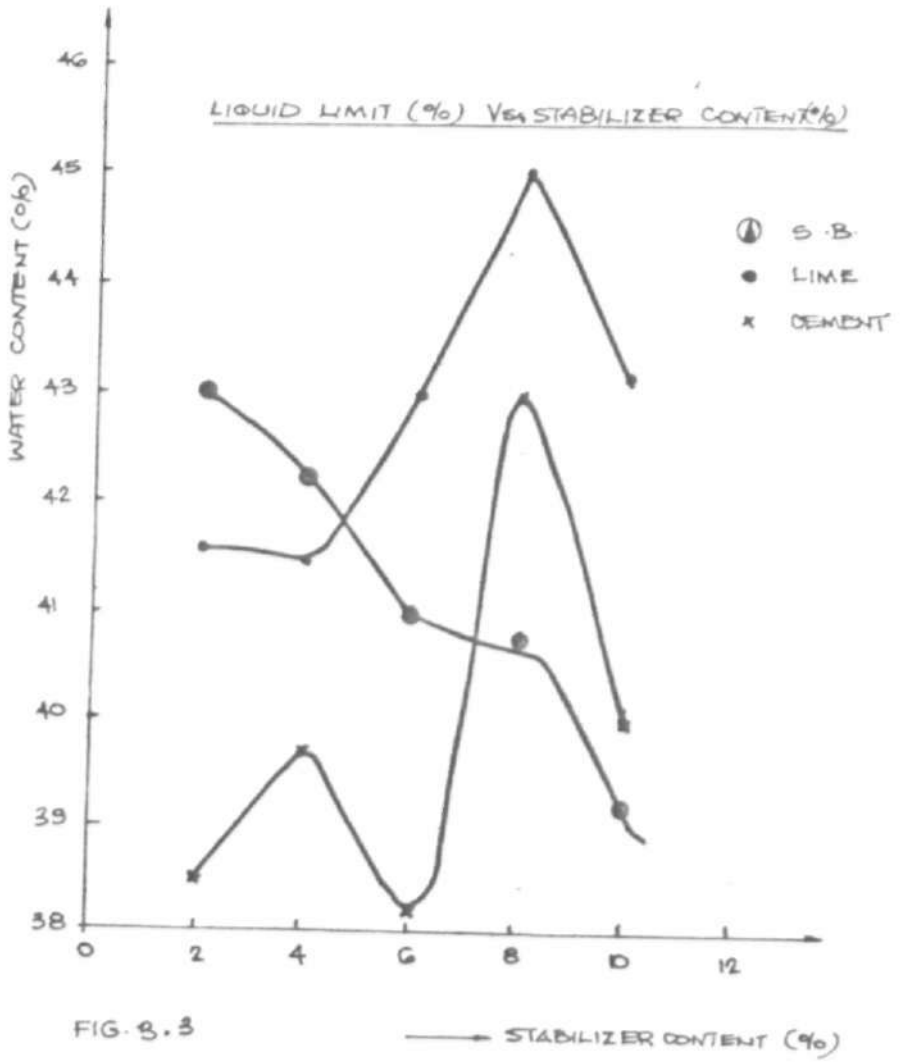

LIQUID LIMIT (%) Vs STABILIZER CONTENT (%)
S.B.
LIME
CEMENT
WATER CONTENT (%)
46
45
44
43
42
41
40
39
38
0
2
4
6
8
10
12
STABILIZER CONTENT (%)

FIG. 3.3

Table 3.3 Effects of Cement on Atterberg Limits of Lateritic Soil

Percentage	Cement	Liquid limit (%)	Plastic limit(%)	PI (%)
0	"	28.70	20.69	7.51
2	"	38.50	35.6	12.90
4	"	39.70	24.5	15.2
6	"	38.20	20.9	17.3
8	"	43.0	20.4	22.3
10.	"	40.00	23.8	16.2

3.2-2 Determination of the Dry Density/Moisture Content of the Soil-Stabilizer

In determining the dry density/moisture content of the soil-stabilizer mixture, 3kg of soil was taken and the corresponding amount of stabilizer by weight was added and then thoroughly mixed in a head pan. Then 3% ($90cm^3$) of water was added and again thoroughly mixed. This soil-stabilizer mixture was then compacted in a standard proctor mould in three layers giving each layer 25 blows. After this compaction the mass of the mould + base + compacted soil - stabilizer mixture was weighed from which the mass of the compacted soil-stabilizer mixture was determined. The compacted wet soil-stabilizer was then poured into a headpan and a small sample of it was

taken for moisture content determination.

The soil-stabilizer mixture was compacted about six times by adding fixed percentages of water by volume to the sample after each compaction up to the compaction after soil-stabilizer wet weight has fallen. The dry density ρ_d was determined using equation 3.1

$$\rho_d = \frac{100\rho}{1+w} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.1$$

where,

ρ_d - dry density of soil solids.

ρ - bulk density of the soil

w - moisture content of the soil.

The experiment was repeated at different percentages of each stabilizer.

The graphs of dry density were plotted against moisture content, as shown in Appendix C. And the results of the B.S. compaction of the lateritic soil with lime, scale-billet and cement are as summerized in Tables 3.4 - 3.6. Also the results were graphically displayed in figures 3.4 - 3.5.

Table 3.4 Effects of lime on Compaction Characteristic of Lateritic Soil

% of Stabilizer	OMC (%)	MDD (KN/m^3)
0	16.50	17.09
2	17.50	17.32
4	18.00	16.70
6	21.80	15.75
8	18.00	16.85
10	17.25	15.36

Table 3.5 Effects Billet Scales on Compaction Characteristic of Lateritic Soil

% of Stabilizer	OMC (%)	MDD (KN/m^3)
0	16.50	17.09
2	18.50	16.74
4	20.00	16.70
6	17.50	16.70
8	18.00	17.32
10	19.00	17.07

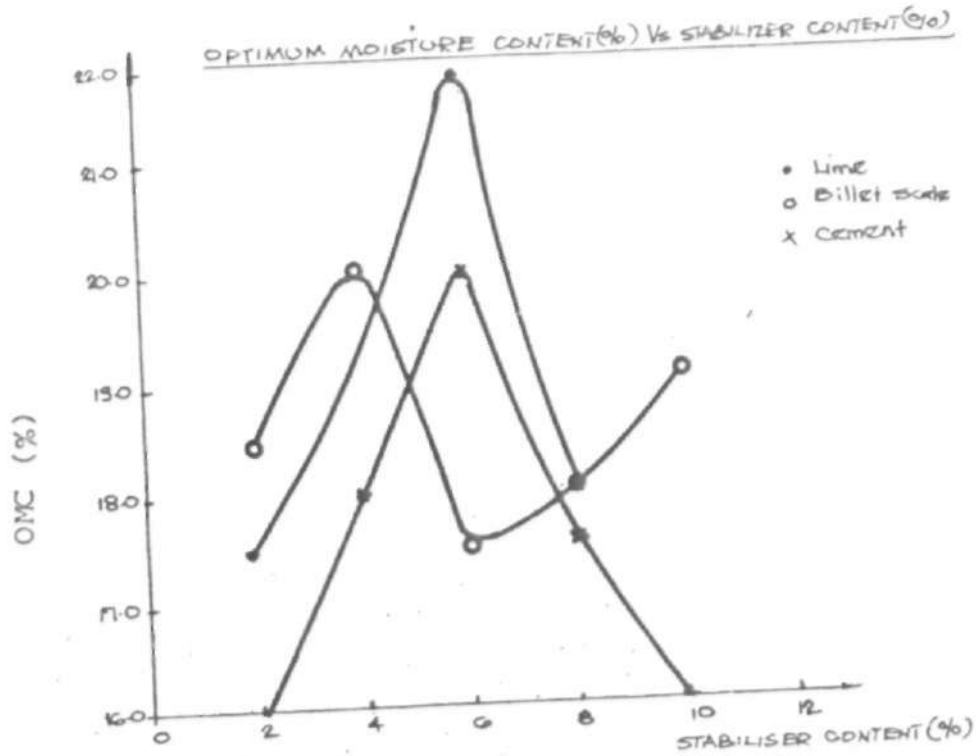

OPTIMUM MOISTURE CONTENT(%) Vs STABILIZER CONTENT(%)
OMC (%)
22.0
21.0
20.0
19.0
18.0
17.0
16.0
0
2
4
6
8
10
12
STABILISER CONTENT (%)
• Lime
o Billet scale
x cement

FIG 3.4

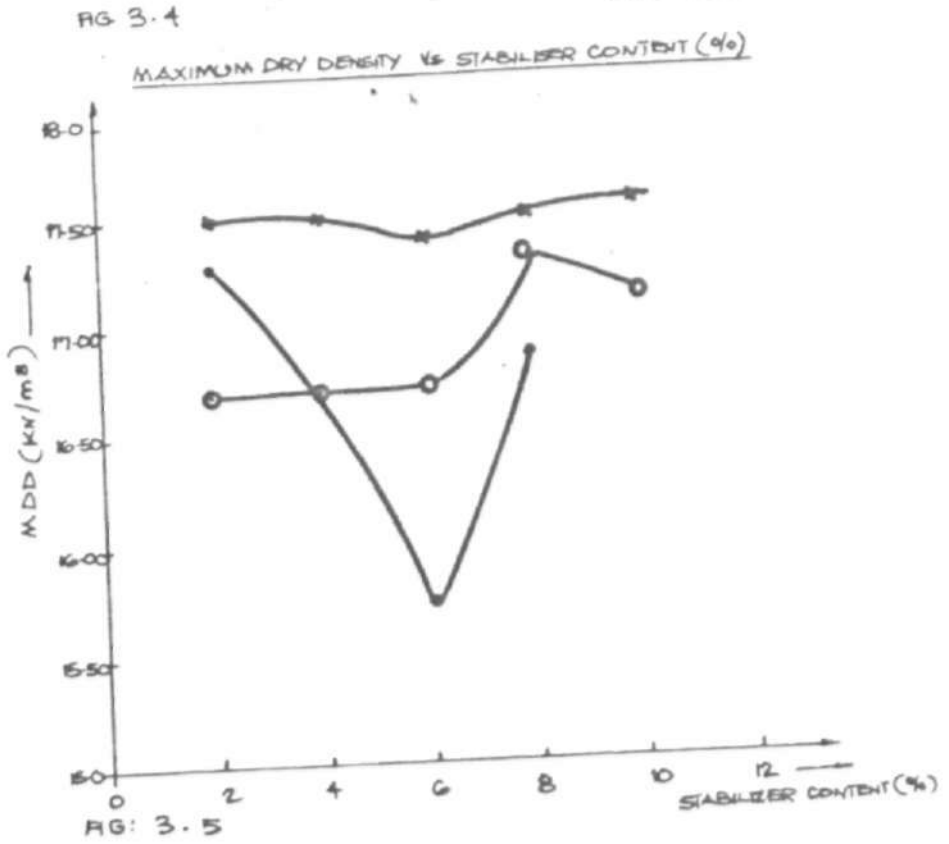

MAXIMUM DRY DENSITY Vs STABILIZER CONTENT (%)
MDD (KN/m³)
18.0
17.50
17.00
16.50
16.00
15.50
15.0
0
2
4
6
8
10
12
STABILIZER CONTENT (%)

FIG: 3.5

Table 3.6 Effects of Cement on Compaction Characteristic of Lateritic Soil

% of Stabilizer	OMC (%)	MDD(KN/m^3)
0	16.50	17.09
2	16.00	17.53
4	18.00	17.50
6	20.00	17.40
8	17.50	17.48
10	16.00	17.56

3.2-3 Determination of the Particle Size Distribution of the Soil

The particle size distribution of the soil was found by particle size analysis. An analysis of this kind quantitatively expresses the proportions by weight of various sizes of particles present in the soil. It is of serious significance in several problems in soil engineering e.g. concrete mixes, highway base and sub-base, design of protective filter, filter drains for earth dams and water wells etc.

In order to analyse the soil, the combined sieve analysis was used, the particle size distribution of its coarse fraction was determined using B.S. Sieves and that of its fine fraction was done

by sedimentation analysis.

The result of sieve analysis was recorded in Test Data Sheet 302 and the calculated particle size and the fraction finer (P) of particle finer than D was presented in Test Data Sheet 302 and the results of dry sieving and sedimentation analysis were combined in Test Data Sheet 303 all in Appendix A.

The diameter (D) and fraction finer (P) than D were calculated using equations 3.2 and 3.3 respectively

$$D = K\left(L/t\right)^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.2$$

where,

$$K = \left(18\eta/(\gamma_s - \gamma_w)\right)^{\frac{1}{2}}$$

$$P = aXR_c/W \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.3$$

where,

$R_c = R_a + C_T$

$a = 1.53 - 0.2Gs.$

R_c = corrected hydrometer reading

R_a = reading at the top of miniscus

C_T = the composite correction factor

G_s = the relative density of the soil particles.

3.2-4 The California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test is an adhoc penetration test developed by the California State Highway Department for the evaluation of subgrade strengths and later extended to fill, sub-base and base materials, In which the load required to cause a plunger of standard size to penetrate a specimen of soil at a standard rate is measured either before or after the specimen has been soaked for some days. Therefore, California Bearing Ratio is a measure of the shearing resistance of soil under carefully controlled density and moisture conditions and is used with empirical curves for designing flexible pavements. It is expressed as a percentage of the unit required to force a piston into the soil divided by the unit load required to force the same piston to the same depth into a standard sample of crushed stone.

5kg of the lateritic soil was mixed with the various percentages of the chosen stabilizers and throughly mixed and then mixed with the calculated Optimum moisture content as determined from standard

B.S. compaction. It was then compacted in three layers, each layer was given equal number of blows 25 ; Two specimens were prepared, one with unperforated CBR mould and the other with perforated CBR mould. The former was taken to the CBR testing machine to determine the loads corresponding to various penetrations. While the later was soaked for 24 hours before testing. In both cases the specimen were tested at the top and bottom and the readings were recorded in as shown in CBR report sheets.

The soaking is done in order to simulate the soil or soil-stabilizer to the worst condition, which exist subsequent to construction. Therefore the soaking is done to assess, if the soil will resist seepage and whether it will withstand water that stays on the road as a result of rainfall that lasts for hours or even days.

The results of the CBR test are as presented in Tables 3.7 - 3.9 and the results were also graphically represented as in figures 3.6-3.7 for soaked and unsoaked conditions.

Table 3.7 Effects of Lime on CBR of Values of Lateritic Soil

% of stabilizer	0	2	4	6	8	10
Unsoaked	14.94	16.87	30.84	10.60	15.42	13.49
Soaked	4.63	13.39	14.75	12.72	9.16	4.14

Table 3.8 Effects of Billet-Scales on CBR Values of Lateritic Soil

% of scale-billet	0	2	4	6	8	10
Unsoaked	14.94	12.85	17.35	23.13	20.24	11.08
Soaked	4.63	7.20	4.63	12.34	10.79	7.71

Table 3.9 Effects of Cement on CBR Values of Lateritic Soil

% of cement	0	2	4	6	8	10
Unsoaked	14.63	23.77	22.17	25.98	21.84	24.09
Soaked	4.63	25.54	81.92	39.51	66.18	80.95

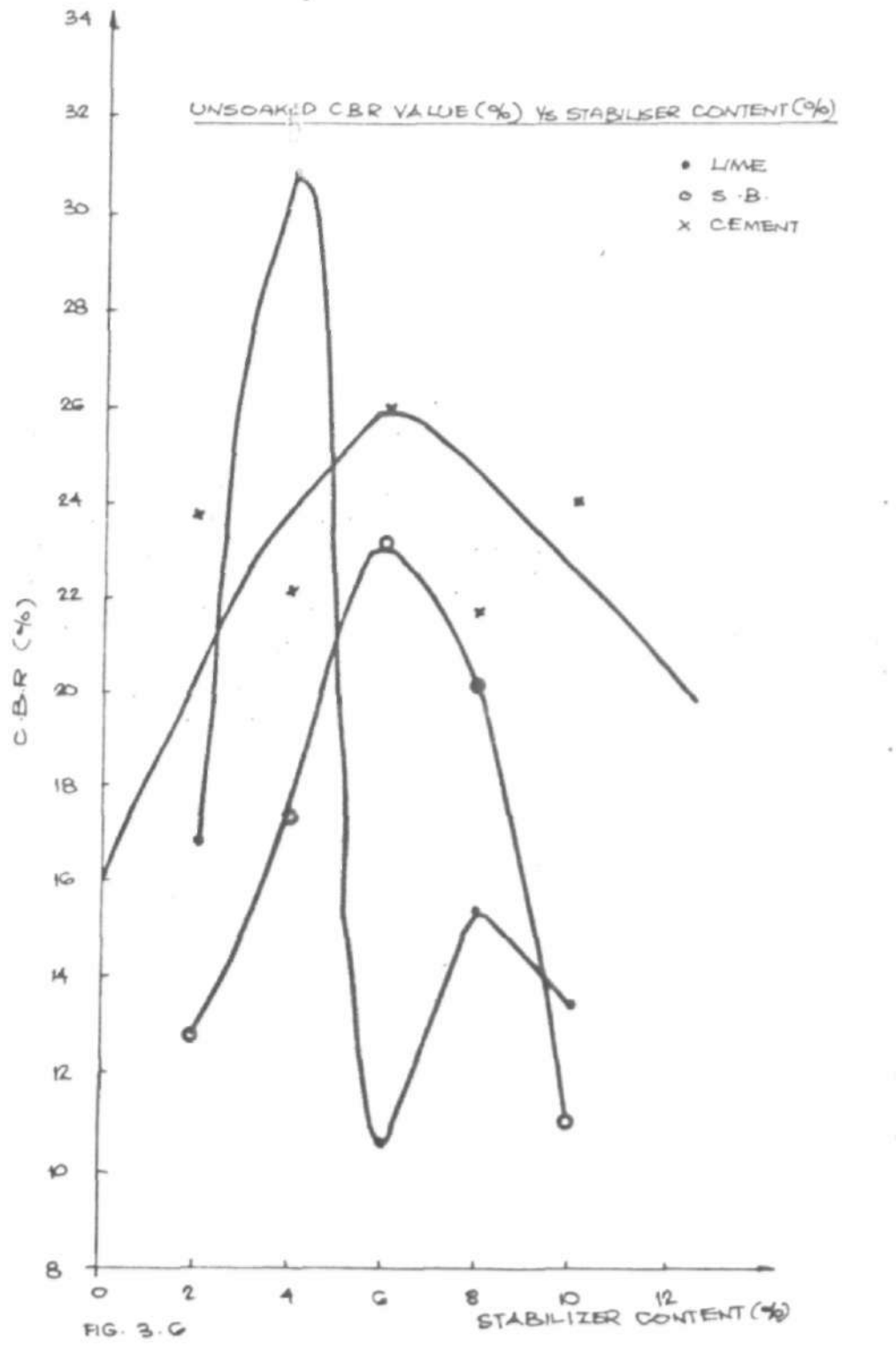

UNSOAKED C.B.R VALUE (%) Vs STABILISER CONTENT (%)
• LIME
o S.B.
x CEMENT
C.B.R (%)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
0
2
4
6
8
10
12
STABILIZER CONTENT (%)

FIG. 3.6

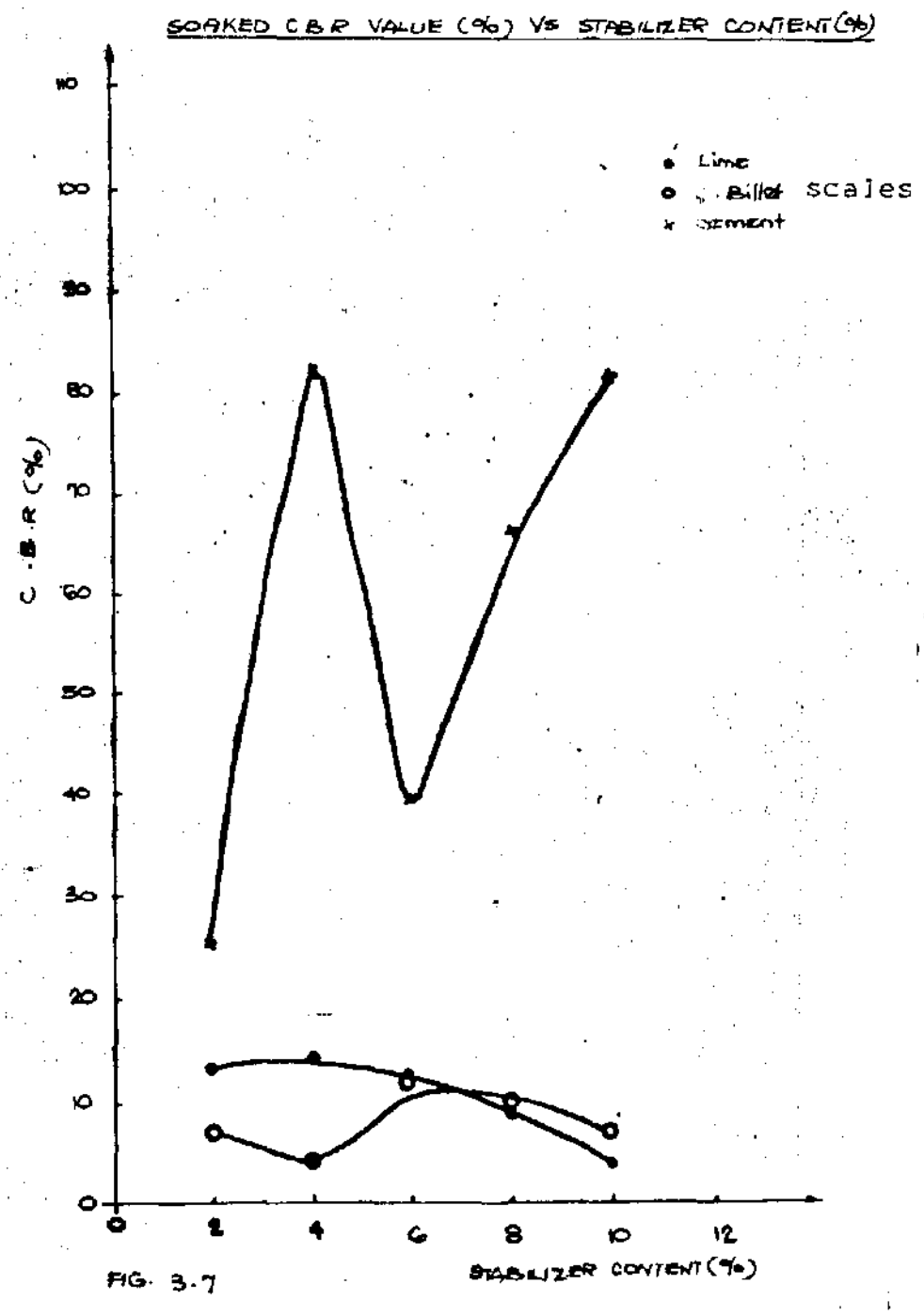

SOAKED C.B.R VALUE (%) Vs STABILIZER CONTENT(%)
Lime
Billet scales
Cement
C.B.R (%)
0
10
20
30
40
50
60
70
80
90
100
110
0
2
4
6
8
10
12
STABILIZER CONTENT (%)

FIG. 3.7

3.2-5 Moisture Content and Specific Gravity Determination

The initial moisture content of the soil sample as well as the specific gravity were calculated and the averaged values are presented below. The test data sheet as shown in Appendix A.

1. Moisture content = 7.33%
2. Specific gravity = 2.64.

CHAPTER FOUR

4.0 DISCUSSSION OF TEST RESULTS

4.1 GRADING ANALYSIS

The particle size distribution of the natural soil has been presented as a curve on a semi-logarithmic plot in Fig.4.8. The lack of continuity of the resultant curve for the grading analysis can be attributed to different assumptions in defining the equivalent particle size diameter.

It can be seen that the particles lie within a steep curve, indicating that the particles lie within a small range. Values obtained from the calculated coefficient of uniformity and coefficient of curvature also give good insights. According to the uniformity coefficient criterion, the soil is well-graded. However, it fails the coefficient of curvature criterion by not lying between 1 and 3, Robert D.H. and William D.K., 1981. Therefore based on coefficient of curvature. It is poorly graded. Therefore it is indeed poorly (narrowly) graded.

$$C_u = \frac{D60}{D10} = \frac{0.65}{0.02} = 32.50$$

$$C_c = \frac{(D30)^2}{D10 \times D60} = \frac{(0.35)^2}{0.02 \times 0.65} = 9.42$$

where;

D10 = the particle size which is such that 10% by mass of the particles are smaller.

D30 = the particle size which such that 30% by mass of the particles are smaller.

D60 = the particle size which is such that 60% by mass of the particles are smaller.

Also the parcentages of gravel, sand, silt and clay have been calculated. The results are summarised in Table 4.1. On the basis of the resuts the soil is considered to be silty-sand.

Table 4.1: Constituents of the Lateritic Soil

Constituents	Percentages (%)
Gravel	3.33
Sand	78.58
Silt	15.01
Clay	3.08

Since the liquid limit = 28.20%, plasticity index = 7.51% and with less than 35% of the soil passing No. 200 B.S. sieve the soil is classfied as A-2-4, using AASHTO classification system.

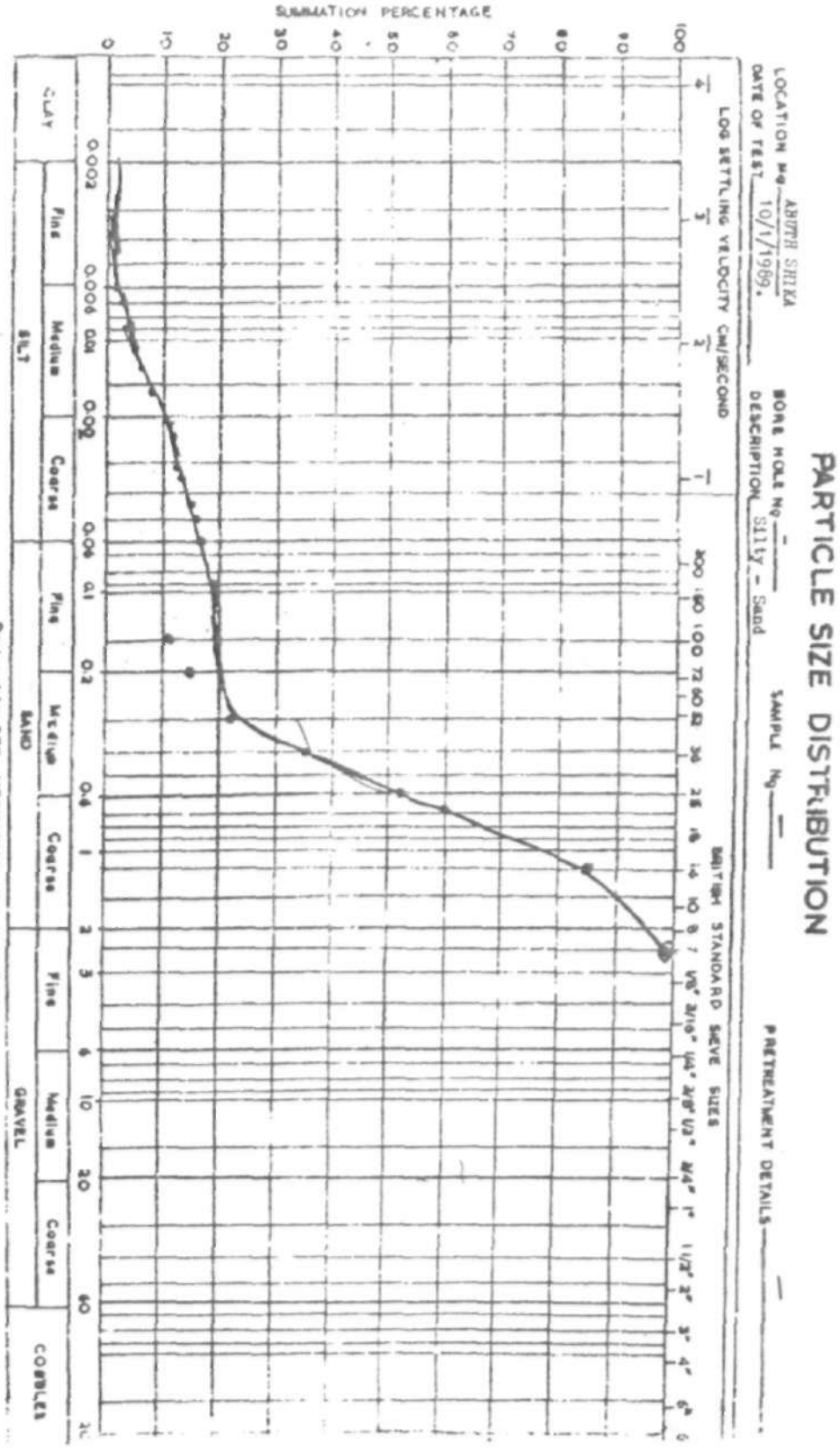


Fig.4.8: Particle Size distribution of Shika Lateritic Soil.

4.2 CEMENT - STABILIZATION

4.2-1 Atterberg Limits

The results of Atterberg Limits on the natural soil with various percentages of cement are as presented in Table 3.3. The nature of changes of liquid limit, plastic limit, and plasticity index has been presented in figure 3.1 to 3.3. The liquid limit increases from 2% cement to 4% and then decrease at 6% and later increased to the maximum at 8% cement. While the plastic limit decreases from 2% of cement to 8% cement and suddenly jumped. The plasticity index increases from 5.0% for the control to 22.3 for 8% cement.

A substantial reduction in plastic limit of soil-cement mixture upon the addition of Portland cement can be noted. While there is a substantial increase in plasticity index resulted from the addition of portland cement.

4.2-2 Dry Density/Moisture Content Relationship

The results of standard proctor compaction test with various percentages of cement have been presented in Table 3.6.

The changes in optimum moisture content

(OMC) and Maximum Dry Density (MDD) with increase in cement content have been presented as in Figures 3.4 and 3.5.

The Maximum Dry Density showed an appreciable increase from 0% to 2% and thereafter decrease, until at 10% cement where the maximum occured. While the OMC has the minimum at 2% and 10% and maximum at 6% cement.

4.2-3 California Bearing Ratio(CBR) Test

The results of both unsoaked and soaked CBR tests have been shown in Table 3.9. The trend of changes of both soaked and unsoaked CBR values has been presented in figures 3.6 and 3.7 respectively

The change of unsoaked CBR values showed an increase from the control test and has the maximum at 6% cement. While the soaked CBR values showed a significant increment with maximum at 4% cement.

4.3 LIME - STABILIZATION

4.3-1 Atterberg Limits

The results of Atterberg Limits on the natural soil and with natural soil with various percentages of lime has been presented in Table 1.1. The nature of changes of liquid limit, plastic limit and

and plasticity index has been presented in figures 3.1 to 3.3.

The liquid limit appreciably change from the 0% to 2% and slightly decrease at 4% there after increase with the maximum at 8% lime. While the nature of changes in plastic limit didn't follow any pattern, but only having a maximum at 8% lime and minimum at 6% lime. In the case of plasticity index there is generally an increase in PI values with maximum at 6% lime and minimum at 4% lime.

4.3-2 Dry Density/Moisture Content Relationship

The results of standard proctor compaction test on the natural soil and with natural soil with various percentages of lime have been presented in Table 3.4.

The nature of changes in the optimum meisture content shows an increase up to a maximum at 6% lime and ther after decreased to minimum at 10% lime.

While the maximum dry density increase to the maximum at 2% lime and thereafter, couldn't follow any definite pattern.

4.3-3 California Bearing Ratio (CBR) Test

The results of both unsoaked and soaked CBR tests have been shown in Table 3.7. The trend of changes of both soaked and unsoaked CBR values has been graphically presented in figures 3.6 and 3.7.

The unsoaked CBR values change with the maximum at 4% lime and minimum at 6% lime. While the soaked CBR values has the maximum at 4% lime and minimum at 10%.

4.4 BILLET-SCALES - STABILIZATION

4.4-1 (a) Atterberg Limits

The result of atterberg limits on the natural soil and natural soil with various percentages of billet-scale has been presented in Table 3.2. The trend of changes of liquid limit with increase percentage of billet-scale shows a slight decrease with maximum at 2% billet-scale and minimum at 10% billet-scale. While the plasiic limit changes with maximum at 10% billet-scale and minimum at 4% billet-scale. In the case of plasticity index, there is an increase up to 4% billet-scale and then decrease to the minimum at 10% billet-scale.

4.4-2 Dry Density/Moisture Content Relationship

The results of standard proctor compaction test with various percentages of billet-scale

have been presented in Table 3.5.

The nature of changes in optimum moisture content and maximum dry density have been presented in figures 3.4 and 3.5.

The maximum dry density decreases at 4% billet-scale to a maximum at 8% billet-scale. While the optimum moisture content increases with maximum at 4% billet-scale and minimum at 6% billet-scale.

4.4-3 California Bearing Ratio (CBR) Test

The results of both unsoaked and soaked CBR tests have been shown in Table 3.8. Also the trend of changes of both soaked and unsoaked CBR values have been graphically presented in figures 3.6 and 3.7.

The change of both unsoaked and soaked CBR values for billet-scale has not been quite substantial and can be vitualised in Table 3.8.

4.5 COMPARISON

The effectiveness of each of the used stabilizers has been discussed. It can be seen that, there is generally an increase in liquid limit in the case of lime stabilisation, while a decrease in

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BAUCHI, NIGERIA.

liquid limit in the case of billet-scale, while there is generally no definite pattern in the case of cement. Also the plasticity, which is a measure of clay content generally showed an increase in lime and cement, while a decrease is noted for billet-scale.

The maximum dry density showed some slight decrease in value at the compactive effort test, as for cement and lime, while there is some increase in maximum dry density in the case billet-scale.

The soaked CBR vaues showed an increase in CBR values up to 14.75% at 4% lime, while a maximum of 12.34% at 6% Billet-scale. The most substantial increase was noted in the case of cement at 4% cement. In the case of unsoaked CBR values, a maximum value of 30.84% at 4% lime was noted, while the maximum in the case of billet-scale is 23.13% at 6% billet-scale. However, a maximum of 25.98% CBR at 6% cement was obtained.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Ideally, the base course of a pavement should consist of gravel or crushed stone, meeting required strength conditions. However, more often than not, the required materials might not be readily available. It is important to note also that road pavement and their foundations are subjected not only to mechanical stress incidental to their usage, but also in dynamic interattions with their environment.

Consequently the selected soil was classified, as A-2-4 group, using the AASHTO classification system and was found out not to satisfy both the CBR value and plasticity index in the soaked condition for the fill, sub-base and base materials. Hence the natural soil was stabilized with cement, lime and billet-scale not merely to increase the strength or shear resistance or the improvement of any other physical property of the soil. But it must supply a defence mechanism against the continually acting dynamic forces associated with the subjection of the soil system to daily and seasonal temperature and moisture changes.

The General Specifications for Roads and Bridges, Federal Republic of Nigeria stipulates: The minimum strength of the various pavement components, determined at maximum dry density and optimum moisture content by either West African Standard Compaction or Modified AASHO compaction tested after at least 24 hours soaking, to simulate the worse-condition, should be

(i) Fill material CBR = 10% up wards

(ii) Sub-base material CBR = 25 - 55%

(iii) Base material CBR = 80% up wards

(iv) Any material of which more than 35% passes the No. 200 B.S. sieve may be rejected.

(v) That the soil should have a plasticity index of not less than 10% and not more than 20%.

Throughout my research work the standard proctor compaction method was used, hence with lesser compactive effort than any of the two method stated above. However, on the basis of the results obtained with standard B.S. compaction on the stabilized soil, the following deductions can readily be drawn.

The natural soil had satisfied the percentage passing the No. 200 B.S. sieve, hence it couldn't

be rejected on the basis of that criterion. So also with the addition of each of the used stabilizers, the plasticity requirement was greatly improved right at 2% stabilizer to the upper limit of the range tested.

However, the strength requirement assessed through the C.B.R values of the unsoaked test had not shown any appreciable increment. While the soaked CBR test in the case of cement-stabilization had shown a remarkable improvement. From the results of the study, with 2% of lime, 2% cement and 2% billet-scale, the unsuitable material can meet the CBR requirement as a fill material.

Again with 4% lime, 2% cement and 6% billet-scale, the silty-sand will meet the CBR requirement as a sub-base material. But only 4% of cement is required to effectively stabilize the A-2-4 group of soil as a base material.

It was unfortunate, that for this group of soil, there was no linearity in any of the properties tested hence no projection can be done with certainty. But as stated earlier soil-stabilization is not merely to increase the strength, but an improvement of other physical properties.

5.2 RECOMMENDATION

Within the range of percentages tested only cement stabilized the soil to be used for base construction, it could be said that, lime is not an effective means of stabilizing silty-sand as previously noted in the literature review. However billet-scale cannot be commented with certainty, until higher percentages are tested. And also particles passing No. 36 B.S. sieve was used because about 40% passed through this sieve and this particle size was chosen as it is about the size of cement. Furthermore, more research should be undertaken with billet-scale coarser than particles No. 36 B.S. sieve to completely assess, how this waste product could be fully utilized.

However, the following recommendations can be made. A-2-4 group of soil can be effectively stabilized with 2% each of lime, cement and billet scale as a fill material. Also with 4% lime, or 2% cement, or 6% billet-scale A-2-4 group of soil can be improved to sub-base material.

Again more research should be done, on this group of soil with higher compactive effort, i.e. West African Compaction and Modified AASHO Compaction methods. And also the strength should be assessed through unconfined compression strength test.

Billet-scale, a waste product, which proves very expensive for its disposal can be utilized as a substitute to cement, especially in areas where Steel Rolling Mills are located. This is because billet-scale is heavy, hence it will require heavy transport cost to take billet-scale to very distant place.

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APPENDIX A.

PRELIMINARY TESTS RESULTS ON BASIC SOIL SAMPLE FROM ABUTH STILL UNDER CONSTRUCTION.

DETERMINATION OF SPECIFIC GRAVITY OF THE SOIL SAMPLE FROM ABUTH SHIKA

Bottle No	1	2	3	Ave
Wt. of bottle + Water (full) W_4	345.1	349.0	348.10	
Wt. of bottle + soil + water W_3	384.6	391.8	386.70	
Wt. of bottle + soil W_2	159.3	168.6	161.60	
Wt. of addit. of water (W_4-W_1)	95.7	99.7	98.7	7.64
Wt. of water added to soil (W_3-W_2)	249.4	249.4	249.4	
Wt. of soil $(W_2 - W_1)$	225.3	22 .2	225.10	
Wt of water displaced by soil $(W_4 - W_1) - (W_3 - W_2) = W$	24.1	26.1	24.3	
Specific gravity of soil particles $(W_2 - W_1)/W$	2.639	2.639	2.588	

DETERMINATION OF MOISTURE CONTENT

Bottle No.	131	173	193
Bottle + Wet soil	46.3	48.6	43.00
Bottle + dry soil	43.70	46.0	40.70
Bottle empty	8.10	8.10	8.10
Dry weight	35.60	37.90	32.60
Loss	2.60	2.60	2.40
Moisture content	77.33	6.86	7.36
Average	7.33		

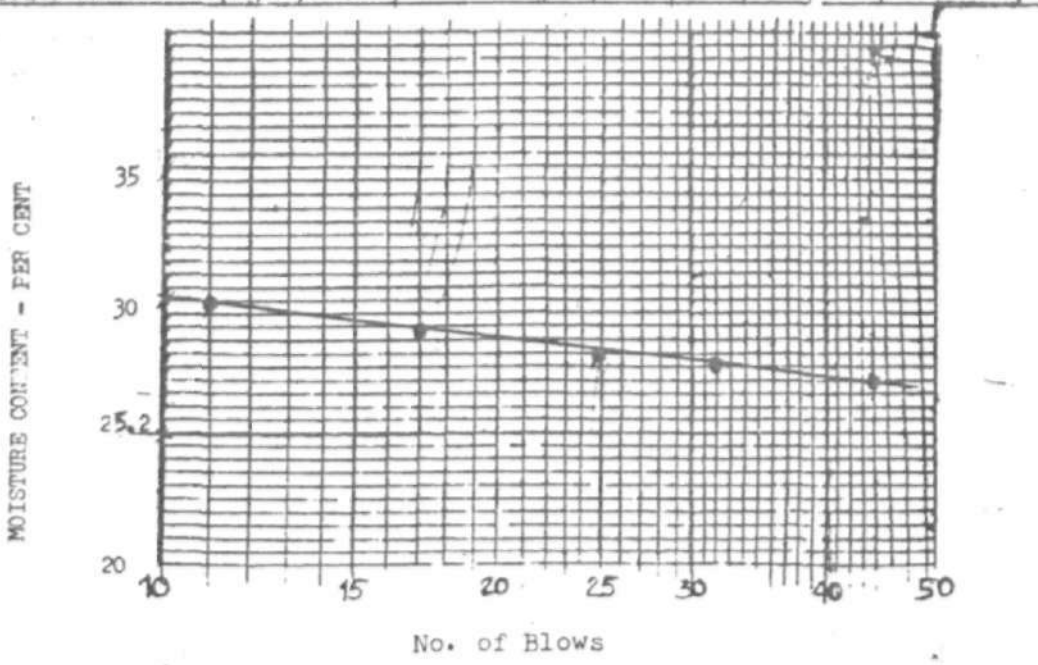
CONTROL (0%)

MATERIAL TEST 0%

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No.....-... Liquid Limit. 28.20..... Plastic Limit. 20.69....
Date.....-..... Plasticity Index..7.51..... Linear Shrinkage. 3.57...
Job.....Project..... Description of soil .....-.....
Site....A.B.U.T.H.....Shika.....
L.L. Machine No..... Operator Awaisu M. M.
Proportion of sample retained on No. 36 B.S. Sieve .....150gms.....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	45		32		25		17		11	
Container No.....	20		49		38		32		22	
Wt of Wet soil & container...g..	20.60		20.00		22.80		19.80		25.4	
Wt of dried soil & container g..	18.20		17.60		20.00		17.5		21.6	
Wt of container..... g...	9.50		8.90		10.0		9.50		9.3	
Wt of dry soil (Wd) g.....	8.70		8.70		10.0		8.00		12.3	
Wt of moisture (Wm/Wd) .....%	2.40		2.40		28.0		2.30		3.8	
Moisture content 100(Wm/Wd)...%	27.0		27.5		28.0		28.7		30.8	
Type of test				PL		PL		PL		
No of blows/shrinkage %.....				-		-		-		
Container No.....				54		40		34		
Wt of wet soil & container... g..				15.1		14.6		14.8		
Wt of dried soil & container...				14.1		13.8		13.8		20.6
Wt of container..... g ..				9.30		9.70		9.20		
Wt of dry soil (Wd)				4.80		4.10		4.60		
Wt of moisture (Wm)..... g ..				1.00		0.80		1.00		
Moisute content 100(Wm/Wd)...%				20.8		19.5		21.7		



Test Data Sheet 301 — Sieve Analysis on Basic Soil Sample (Shika)

Gross mass of soil (M_o) 200gm — Mass passing 2mm sieve (M_1) 187.80gm

Mass retained on 2mm sieve 12.2gm — Mass used in sedimentation analysis (M_2) 187.8gm

Student Name: M. M. AWAISU — Group No: - — Date 10/1/89

Sieve Number	Opening Size (mm)	Mass of Sieve (g)	Mass of Sieve + Soil Retained(g)	Mass of Soil Retained(g)	Corrected Mass Retained (g)	Fraction Retained	Cummulative Fraction Retained	Fraction Passing
7	2.00	-	-	0.1		0.52	0.52	99.48
14	1.00	-	-	2.9		14.95	15.45	84.53
25	.60	-	-	6.4		32.99	48.46	51.54
36	0.40	-	-	3.3		17.01	65.47	34.53
52	0.30	-	-	2.5		12.89	78.36	21.64
72	0.20	-	-	1.5		7.73	86.09	13.91
100	0.15	-	-	0.50		22.58	88.67	11.33
200	0.075	-	-	1.7		8.76	97.43	2.58
Pan				0.5		2.58	100.0	0.00

Test Data Sheet 302 Sedimentation (Hydrometer) Analysis

Gross Mass of soil (M_o)200gm Mass passing 2mm sieve (M_1)187.8gm

Mass used in sedimentation analysis (M_2)50gm Zero Time11.32am

Student Name M. M. AWAISU Group No.- Date: 10/1/1989

Elapsed Time	Hydrometer Reading (g/l)	Temperature (^oC)	Particle Diameter (mm)	Fraction Smaller
20 sec	14.00	20%	0.087	0.2128
40 sec	13.00	"	0.062	0.1627
1.0 min	12.00	"	0.052	0.1727
1min 20 sec	11.50	"	0.045	0.1617
1min 40 sec	11.00	"	0.040	0.1524
2.0 min	10.50	"	0.037	0.1426
2.5 min	10.00	"	0.033	0.1326
5.0 min	9.00	"	0.024	0.1126
10 min	8.00	"	0.017	0.0925
15 min	7.00	"	0.014	0.0725
20 min	6.50	"	0.012	0.0625
30 min	6.00	"	0.010	0.0525
40 min	5.50	"	0.009	0.0424
1 hr	5.00	"	0.007	0.0324
1hr 30 min	5.00	"	0.006	0.0324
2 hr	4.50	"	0.005	0.0224
24 hr	4.00	"	0.002	0.0123

Test Data Sheet 303 Combined Particle size Analysis

Gross mass of soil (M_o) .200gm Mass passing 2mm sieve (M_1) 187.8g

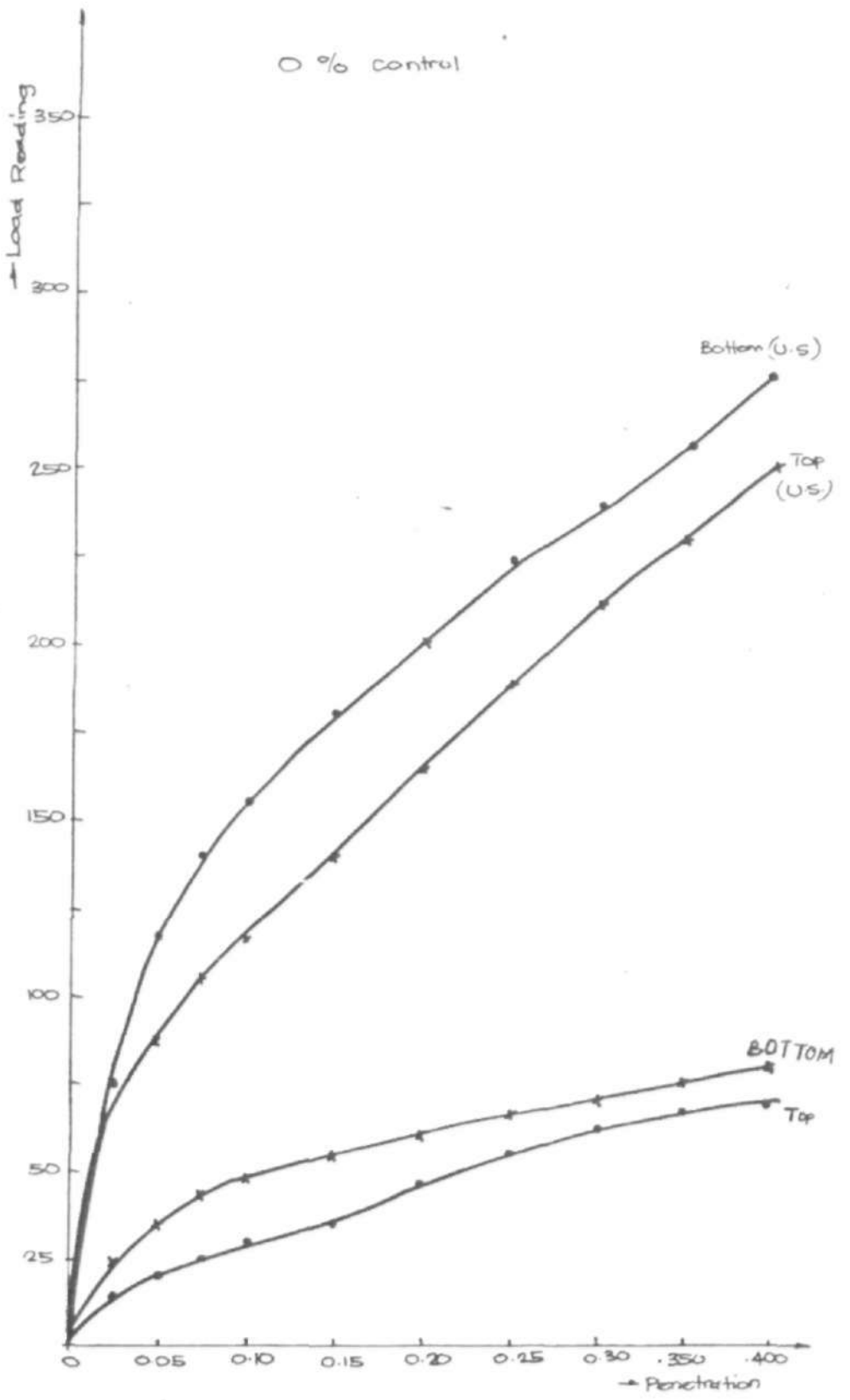
Mass used for sedimentation analysis (M_2) ..50gm.....

Students' Name M.M...AWAISU..... Group No. .....Date 10/11/198

Particl. Size (mm)	Percentage Smaller			
	Sieve Analysis		Hydrometer	
	out of M_o-M_1	out of M_1	out of M_1	of total
2.00	100	100		100
2.00		99.48		99.48
1.00		84.53		84.53
0.60		51.54		51.54
0.40		34.53		34.53
0.30		21.64		21.64
0.20		13.91		13.91
0.15 0.087		11.33		11.33
0.075		2.58	21.28	19.98 2.58
0.062			19.27	18.09
0.052			17.27	16.22
0.045 0.040			16.17 15.27	15.18 14.34
0.037			14.26	13.39
0.033 0.024			13.26 11.26	12.45 10.57
0.017 0.014			9.25 7.25	8.69 6.81
0.012 0.010			6.25 5.25	5.87 4.93
0.009 0.007			4.24 3.24	3.98 3.04
0.006 0.005			3.24 2.24	3.04 2.10
0.002			1.23	2.2

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	70	75	25	15
0.050	87	117	35	20
0.075	104	140	43	25
0.100	116	155	48	30
0.150	139	180	54	35
0.200	163	200	60	47
0.250	188	223	65	54
0.300	210	239	70	61
0.350	229	255	75	67
0.400	250	275	80	69
0.450	271	290	85	73
0.500	293	305	95	84
CBR %	11.17	14.94	4.63	3.02
Average				

CBR RESULT FOR 0% (CONTROL)..... Stabilizer


0 % control
Load Reading
350
300
250
200
150
100
50
25
Bottom (U.S)
Top (U.S)
BOTTOM
Top
0
0.05
0.10
0.15
0.20
0.25
0.30
.350
.400
Penetration

APPENDIX B

LIQUID AND PLASTIC LIMITS TEST RESULTS

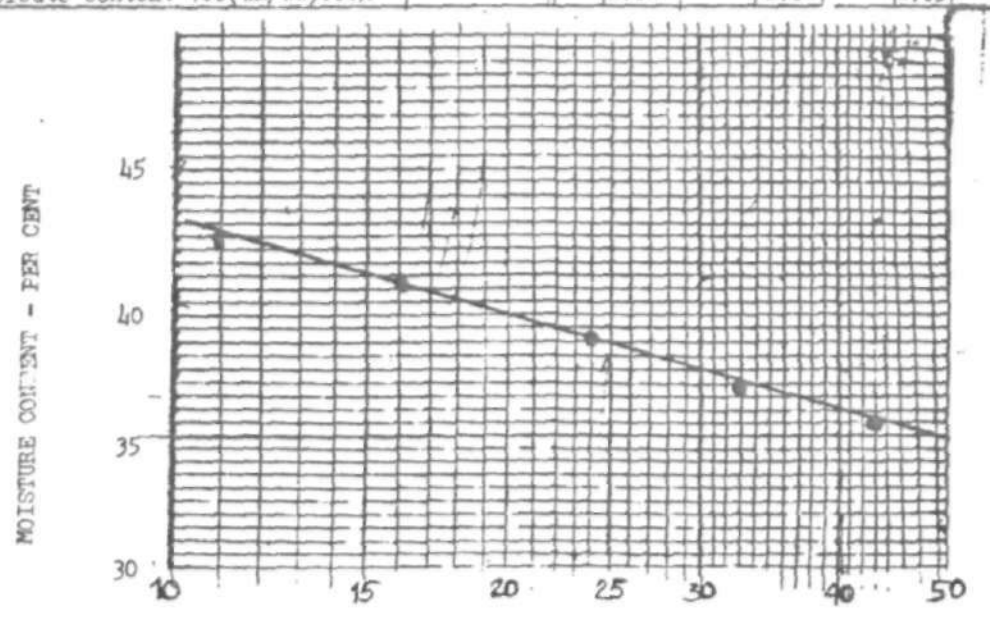
ON THE SOIL - STABILIZERS MIXTURE.

MATERIAL TEST 2% Lime (4gms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit 41.6 ..... Plastic Limit 27.5 .....
Date..... Plasticity Index 14.1 ..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	48		38		24		18		12	
Container No.....	104		302		205		209		605	
Wt of wet soil & container...g..	36.4		38.4		38.6		38.9		38.7	
Wt of dried soil & container g..	32.1		33.4		33.5		33.4		33.1	
Wt of container..... g...	21.2		20.9		21.0		20.8		20.4	
Wt of dry soil (Wd).....	10.9		12.5		12.5		12.6		12.7	
Wt of moisture (Wm/Wd) .....%	4.3		5.0		5.1		5.5		5.6	
Moisture content 100(Wm/Wd)...%	39.4		40.0		40.8		43.7		44.1	
Type of test				PL		PL		PL		
No of blows/shrinkage %.....				-		-		-		
Container No.....				208		406		304		
Wt of wet soil & container... g..				24.1		24.3		25.1		
Wt of dried soil & container...				23.3		23.5		24.2		
Wt of container..... g ..				20.4		20.6		20.9		
Wt of dry soil (Wd)				2.9		2.9		3.3		
Wt of moisture (Wm)..... g ..				0.8		0.8		0.9		
Moisute content 100(Wm/Wd)...%				27.6		27.6		27.3		

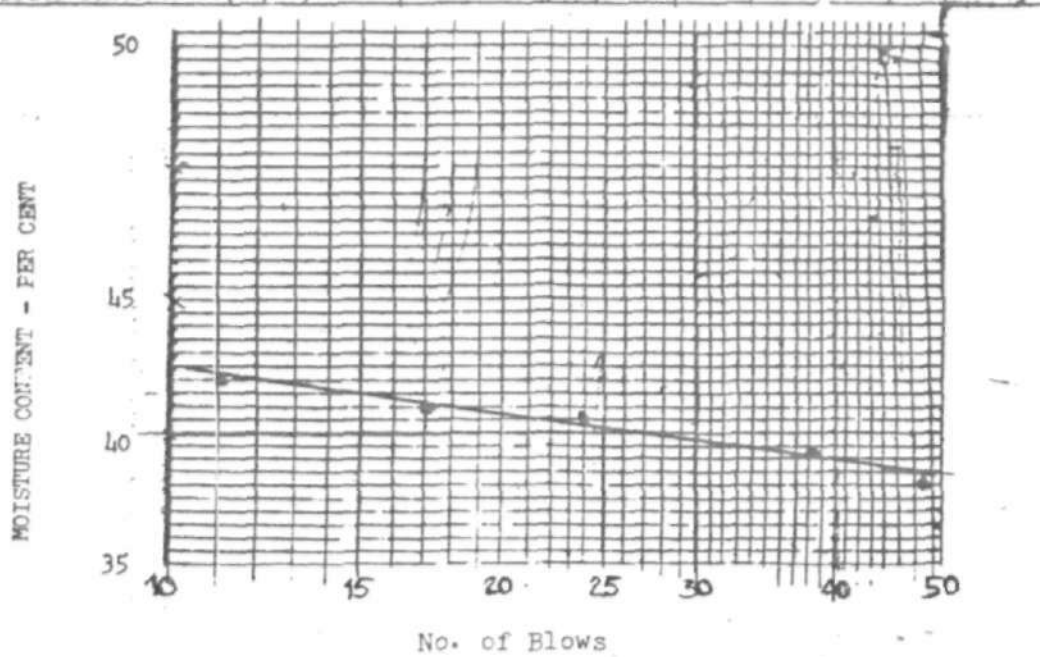


MATERIAL TEST 4½ Lime (8 days)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit...41,5..... Plastic Limit..28,33....
Date..... Plasticity Index.....13.2 Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination. (25)
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	44		34		21		16		12	
Container No.....	200		307		208		204		306	
Wt of Wet soil & container...g..	29.5		38.7		37.6		38.5		38.8	
Wt of dried soil & container g..	25.8		33.9		32.4		32.6		32.9	
Wt of container..... g...	14.9		21.2		20.7		20.1		20.8	
Wt of dry soil (Wd)	10.9		12.7		11.7		12.5		12.1	
Wt of moisture (Wm/Wd) .....%	3.7		4.8		5.2		3.9		5.9	
Moisture content 100(Wm/Wd)...%	33.9		37.8		44.4		47.2		48.8	
Type of test				PL		PL		PL		
No of blows/shrinkage %.....				-		-		-		
Container No.....				201		10		401		
Wt of wet soil & container... g..				25.6		26.0		26.3		
Wt of dried soil & container...				24.5		25.0		25.2		
Wt of container..... g ..				20.6		21.5		21.3		
Wt of dry soil (Wd)				3.9		3.5		3.9		
Wt of moisture (Wm)..... g ..				1.1		1.0		1.1		
Moisute content 100(Wm/Wd)...%				28.2		28.6		28.2		

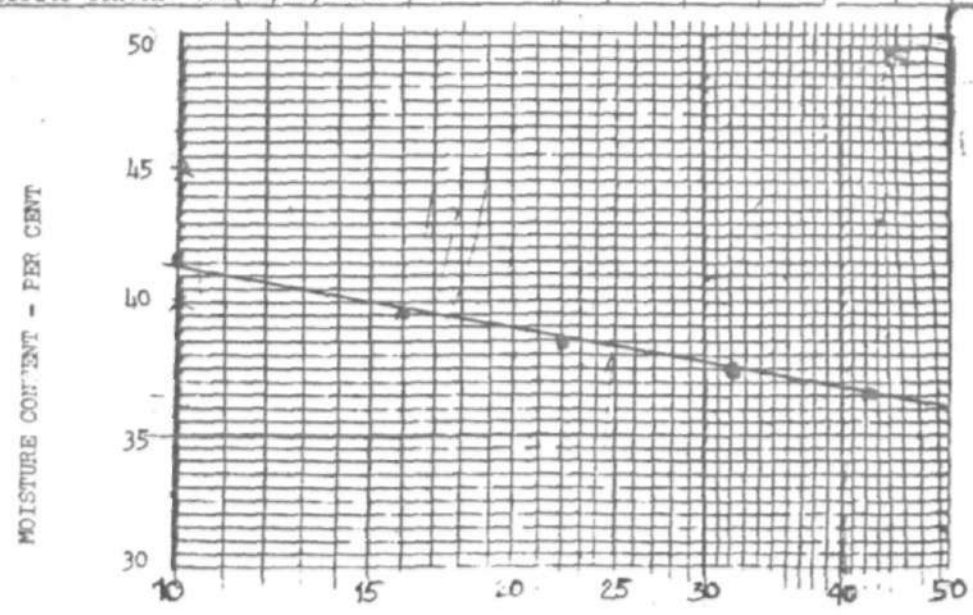


MATERIAL TEST 6% Lime (12gms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit...43.0..... Plastic Limit.23.07.=.23.1
Date..... Plasticity Index.....19.9..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	46		31		22		16		11	
Container No.....	107		309		211		9		206	
Wt of Wet soil & container...g..	39.6		39.2		37.4		37.8		37.7	
Wt of dried soil & container g..	34.6		33.9		32.2		32.5		32.3	
Wt of container..... g...	21.0		21.4		20.3		21.1		21.3	
Wt of dry soil (Wd).....	13.6		12.5		11.9		11.4		11.0	
Wt of moisture (Wm/Wd) .....%	5.0		5.3		5.2		5.3		5.4	
Moisture content 100(Wm/Wd)...%	36.7		42.4		43.7		46.5		49.1	
Type of test				PL		PL		PL		
No of blows/shrinkage %.....				-		-		-		
Container No.....				308		L		203		
Wt of wet soil & container... g..				26.0		25.9		25.7		
Wt of dried soil & container...				25.1		25.0		24.8		
Wt of container..... g ..				21.1		21.1		21.0		
Wt of dry soil (Wd)				4.0		3.9		3.8		
Wt of moisture (Wm)..... g ..				0.9		00.9		0.9		
Moisute content 100(Wm/Wd)...%				22.5		23.1		23.6		

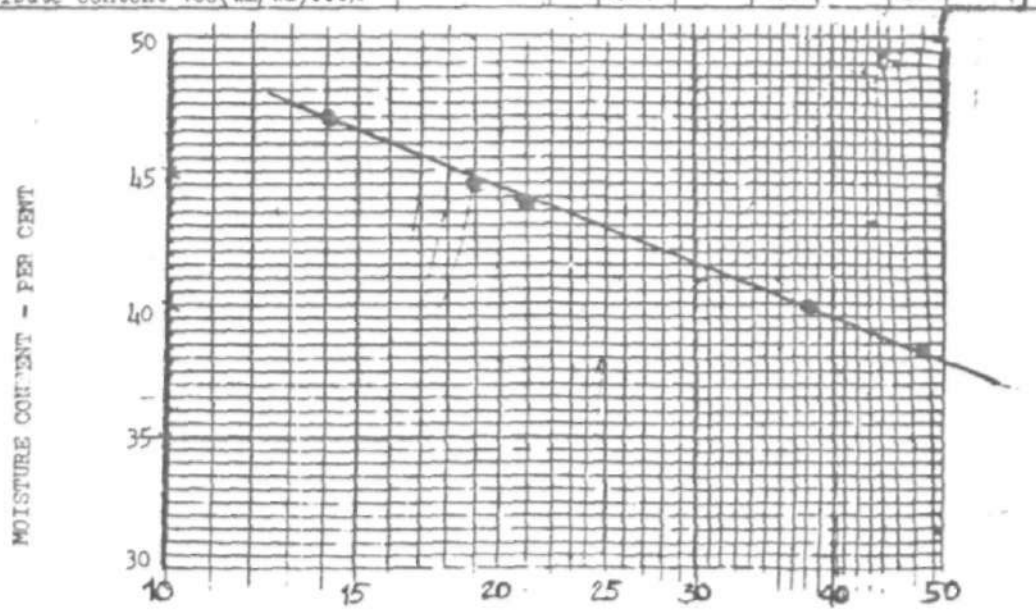


MATERIAL TEST 8% Lime (16gms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit.....45..... Plastic Limit.....28.4.....
Date..... Plasticity Index.....16.6..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	41		31		21		16		12	
Container No.....	402		407		213		209		406	
Wt of Wet soil & container...g..	35.7		37.8		35.6		37.0		35.6	
Wt of dried soil & container g..	31.4		32.6		31.0		31.8		30.4	
Wt of container..... g...	20.5		20.9		20.8		20.9		20.7	
Wt of dry soil (Wd).....	10.9		11.7		10.2		10.9		9.7	
Wt of moisture (Wm/Wd) ....%	4.3		5.2		4.6		5.2		5.2	
Moisture content 100(Wm/Wd)...%	39.5		44.4		45.1		47.8		53.6	
Type of test				PL		PL		PL		
No of blows/shrinkage %.....				-		-		-		
Container No.....				301		109		44		
Wt of wet soil & container... g..				24.9		25.8		25.4		
Wt of dried soil & container...				24.0		24.8		24.5		
Wt of container..... g ..				20.5		21.2		21.4		
Wt of dry soil (Wd)				3.5		3.6		3.1		
Wt of moisture (Wm)..... g ..				0.9		1.0		0.9		
Moisute content 100(Wm/Wd)...%				25.7		27.8		29.0		

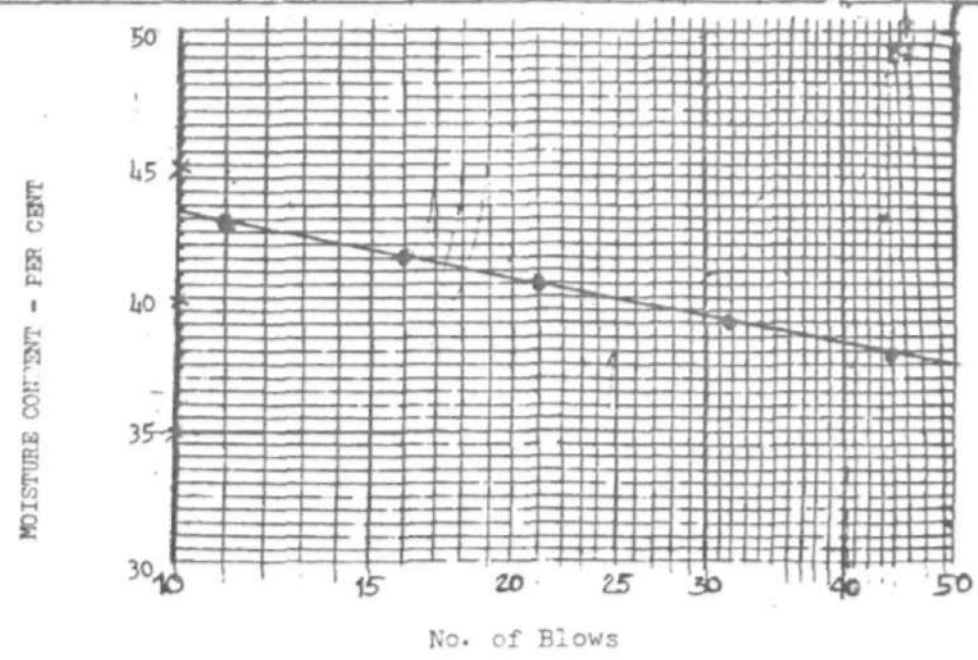


MATERIAL TEST 10% lime (20gms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit...43.2..... Plastic Limit...24.3.....
Date..... Plasticity Index ....18.9..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	48		36		22		18		11	
Container No.....	405		605		202		205		304	
Wt of Wet soil & container...g..	30.0		33.2		36.0		35.8		35.5	
Wt of dried soil & container g..	26.1		29.9		33.3		31.1		32.4	
Wt of container..... g...	14.9		20.5		21.0		21.0		21.0	
Wt of dry soil (Wd).....	11.2		9.4		10.3		10.1		11.4	
Wt of moisture (Wm/Wd) .....%	3.9		3.3		4.7		4.7		6.1	
Moisture content 100(Wm/Wd)...%	34.8		35.1		45.6		46.5		53.5	
Type of test				PL		PL		PL		
No of blows/shrinkage %.....				-		-		-		
Container No.....				1		403		6		
Wt of wet soil & container... g..				18.4		18.9		25.7		
Wt of dried soil & container...				18.4		18.1		24.8		
Wt of container..... g ..				14.5		14.8		21.1		
Wt of dry soil (Wd)				2.9		3.3		3.7		
Wt of moisture (Wm)..... g ..				1.0		0.8		0.9		
Moisute content 100(Wm/Wd)...%				34.0		24.2		24.3		

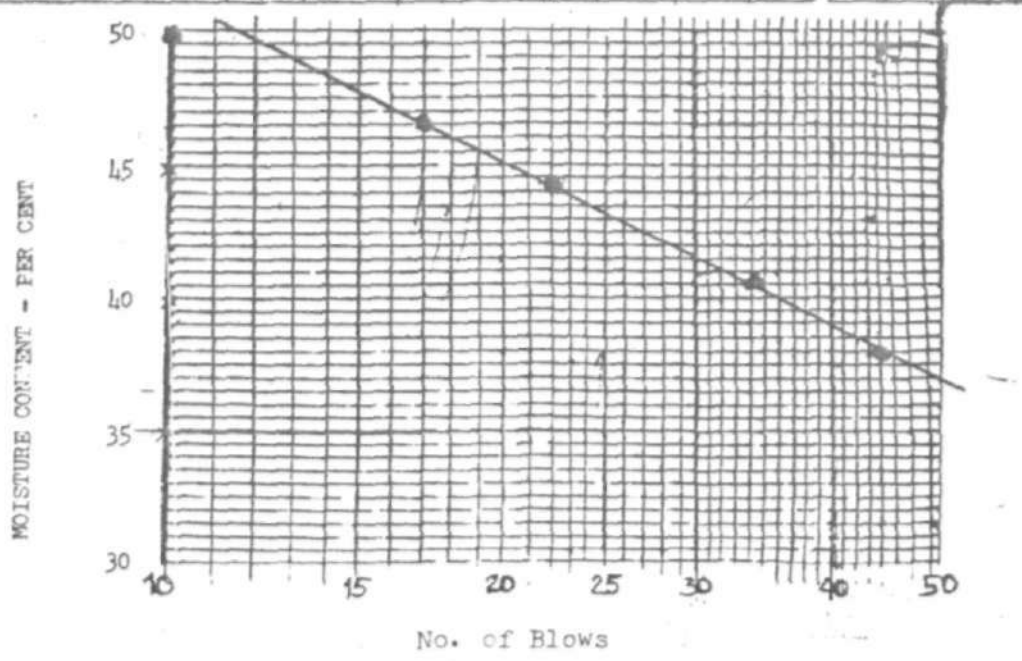


MATERIAL TEST 2% Billet – Joules

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit 43.0 ..... Plastic Limit 23.6 .....
Date..... Plasticity Index 19.4 ..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.E. Machine No..... Operator OKE
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	11		11		11		11		11	
No of blows/shrinkage %....	44		34		22		17		10	
Container No.....	15		74		34		51		52	
Wt of Wet soil & container...g..	24.7		24.7		24.9		25.7		25.7	
Wt of dried soil & container g..	20.7	20.7	20.2		20.0		20.4		20.1	
Wt of container..... g...	9.21	9.2	9.4		9.4		9.0		8.9	
Wt of dry soil (Ww).....	11.5		11.1		10.6		11.4		11.2	
Wt of moisture (Wm/Wd) .....%	4.0		4.5		4.9		5.3		5.6	
Moisture content 100(Wm/Ww)...%	37.8		40.5		46.2		46.5		50	
Type of test						P1		P1		P1
No of blows/shrinkage %.....						-		-		-
Container No.....						44		30		17
Wt of wet soil & container... g..						12.8		12.2		12.3
Wt of dried soil & container...						12.0		11.5		11.6
Wt of container..... g ..						8.6		8.5		8.7
Wt of dry soil (Ww)						3.4		3.0		2.9
Wt of moisture (Wm)..... g ..						0.8		0.7		0.90
Moisute content 100(Wm/Wd)...%						23.5		23.3		24.1

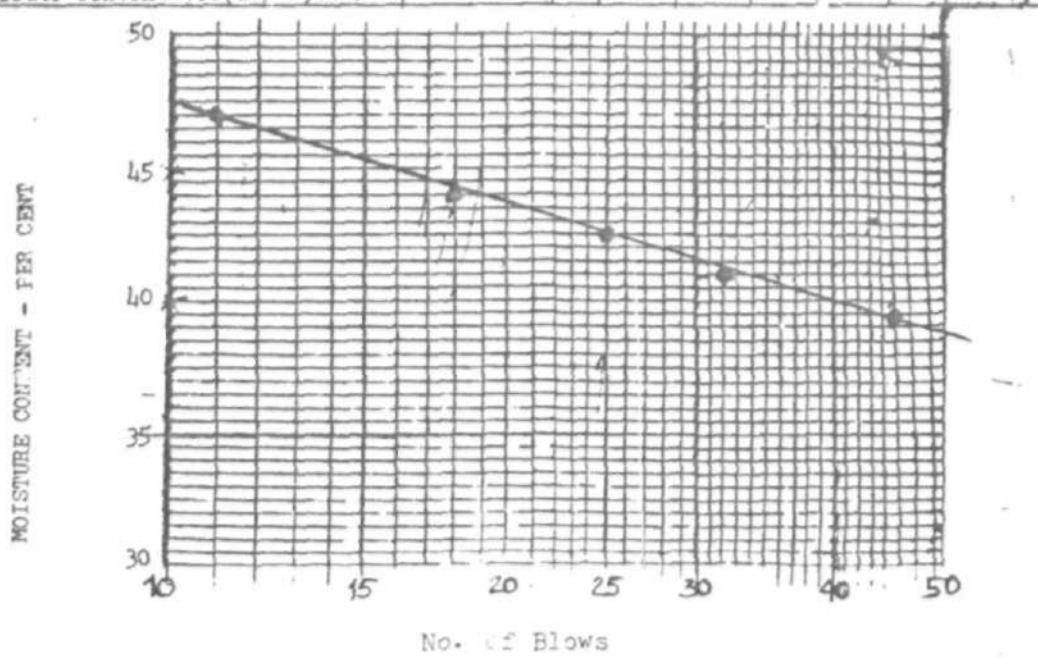


MATERIAL TEST 46 Billet-Scales

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit.....42.3..... Plastic Limit.....22.0.....
Date..... Plasticity Index.....20.3..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator AWAISU M. M.
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	11		11		11		11		11	
No of blows/shrinkage %....	46		33		25		18		11	
Container No.....	8		213		201		207		209	
Wt of Wet soil & container...g..	35.6		38.9		36.8		36.8		35.8	
Wt of dried soil & container g..	31.6		33.6		32.0		31.9		31.0	
Wt of container..... g...	21.2		20.7		20.6		20.8		20.8	
Wt of dry soil (Wd).....	10.2		12.9		11.4		11.1		10.2	
Wt of moisture (Wm/Wd) .....%	4.0		5.3		4.8		4.9		4.8	
Moisture content 100(Wm/Wd)...%	38.5		41.1		42.1		44.1		47.1	
Type of test						P1		P1		P1
No of blows/shrinkage %.....						-		-		-
Container No.....						307		5		32
Wt of wet soil & container... g..						23.8		23.6		23.1
Wt of dried soil & container...						23.3		23.1		22.7
Wt of container..... g ..						21.3		21.1		20.8
Wt of dry soil (Wd)						2.05		2.05		1.9
Wt of moisture (Wm)..... g ..						0.45		0.45		0.4
Moisute content 100(Wm/Wd)...%						22.0		22.0		21.1

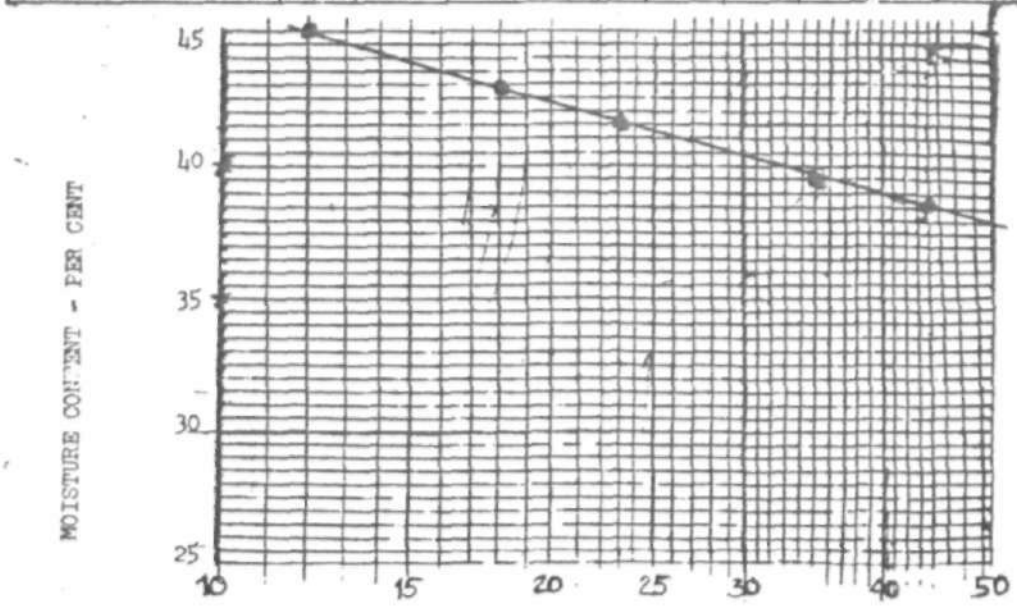


MATERIAL TEST 6% Billet-Scales

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit.41.0..... Plastic Limit.22.7.....
Date..... Plasticity Index.18.3..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator OKE
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	11		11		11		11		11	
No of blows/shrinkage %....	44		36		23		18		12	
Container No,.....	204		206		205		301		209	
Wt of Wet soil & container...g..	33.9		37.0		36.2		34.9		36.7	
Wt of dried soil & container g..	30.6		32.0		31.8		30.5		31.9	
Wt of container..... g...	20.0		21.3		20.9		20.3		21.2	
Wt of dry soil (Wd).....	10.6		10.7		10.9		10.2		10.7	
Wt of moisture (Wm/Wd) .....%	2.3		4.2		4.4		4.4		4.8	
Moisture content 100(Wm/Wd)...%	31.1		39.3		40.4		43.1		44.9	
Type of test						PL		Pl		Pl
No of blows/shrinkage %.....						-		-		-
Container No.....						404		203		209
Wt of wet soil & container... g..						25.4		25.4		24.3
Wt of dried soil & container...						24.6		24.6		23.7
Wt of container..... g ..						21.0		21.1		21.1
Wt of dry soil (Wd)						3.6		3.5		2.6
Wt of moisture (Wm)..... g ..						0.8		0.7		0.6
Moisute content 100(Wm/Wd)...%						22.2		20		23.1

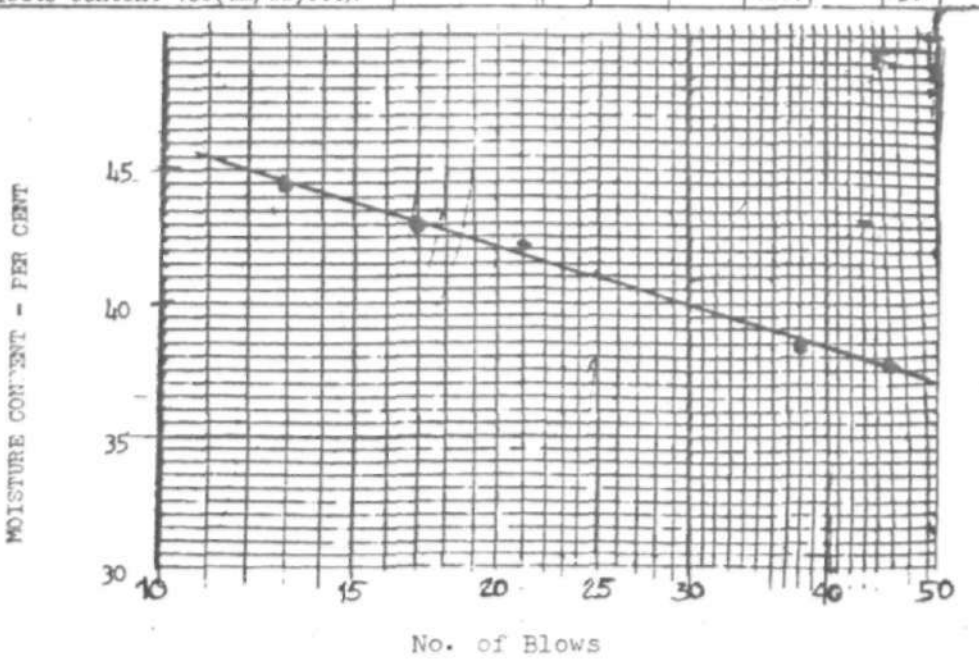


MATERIAL TEST 8% Billet - Soales

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit..40.7..... Plastic Limit..23.1.....
Date..... Plasticity Index...17.6..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator OKE & AWAISU
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	11		11		11		11		11	
No of blows/shrinkage %....	46		38		21		17		13	
Container No.....	202		211		205		208		310	
Wt of Wet soil & container...g..	37.6		39.4		35.6		38.4		36.8	
Wt of dried soil & container g..	33.1		34.1		31.1		33.2		32.0	
Wt of container..... g...	20.9		20.2		20.4		21.0		21.0	
Wt of dry soil (Wd).....	12.2		13.9		10.7		12.2		11.0	
Wt of moisture (Wm/Wd) .....%	4.5		5.3		4.5		5.2		4.8	
Moisture content 100(Wm/Wd)...%	36.9		38.1		42.1		42.6		43.6	
Type of test						Pl		Pl		Pl
No of blows/shrinkage %.....						-		-		-
Container No.....						210		408		212
Wt of wet soil & container... g..						23.3		17.9		24.0
Wt of dried soil & container...						22.8		17.3		23.4
Wt of container..... g ..						20.8		14.9		20.8
Wt of dry soil (Wd)						2.2		2.6		2.6
Wt of moisture (Wm)..... g ..						0.5		0.6		0.6
Moisute content 100(Wm/Wd)...%						22.7		23.1		23.1

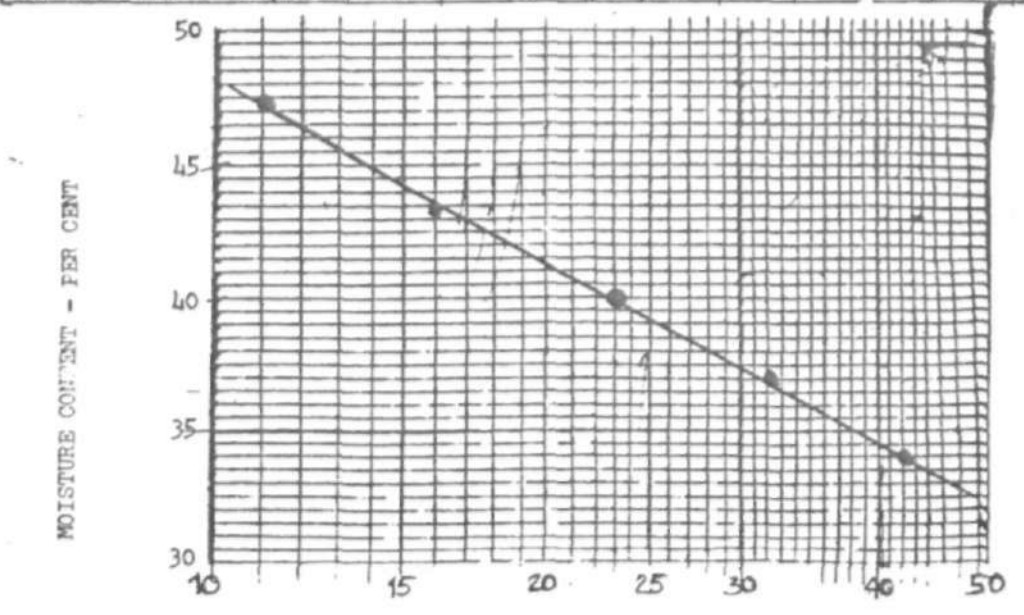


MATERIAL TEST 10% Billet scales

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit..... Plastic Limit. 24.1 .....
Date..... Plasticity Index. 15.1 ..... Linear Shrinkage.....
Job..... Description of soil 10% Billet scales.....
Site.....
L.L. Machine No..... Operator Oke + AWAISU
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	11		11		11		11		11	
No of blows/shrinkage %....	42		32		23		16		11	
Container No.....	104		402		406		207		306	
Wt of Wet soil & container...g..	39.5		36.6		35.6		35.5		34.5	
Wt of dried soil & container g..	34.8		32.2		31.3		31.1		30.1	
Wt of container..... g...	21.1		20.4		20.5		20.9		20.8	
Wt of dry soil (Wd)	13.7		11.8		10.8		10.2		9.3	
Wt of moisture (Wm/Wd) .....%	4.7		4.4		4.3		4.4		4.4	
Moisture content 100(Wm/Wd)...%	34.3		37.3		39.8		43.1		47.3	
Type of test						P1		P1		P1
No of blows/shrinkage %.....						-		-		-
Container No.....						200		407		401
Wt of wet soil & container... g..						18.4		24.7		24.9
Wt of dried soil & container...						17.7		24.0		24.2
Wt of container..... g ..				24.1		14.8		21.0		21.3
Wt of dry soil (Wd)						2.9		3.0		2.9
Wt of moisture (Wm)..... g ..						0.7		0.7		0.7
Moisute content 100(Wm/Wd)...%						24.1		23.3		24.1

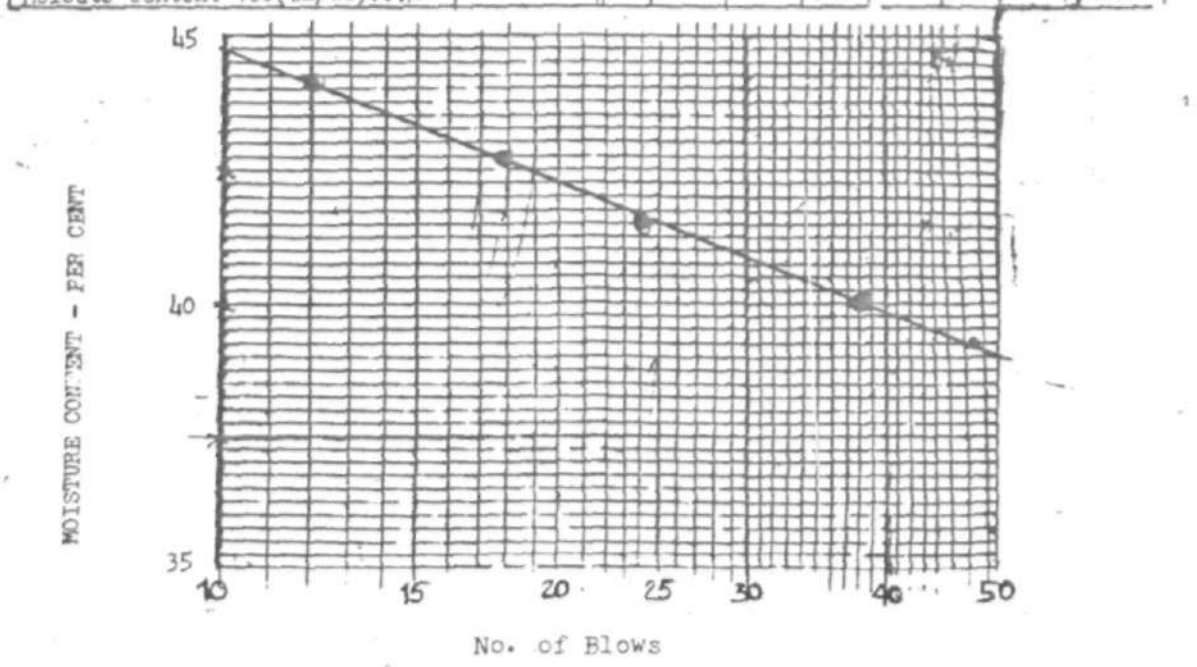


MATERIAL TEST 2% Cement (4gms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit 38.5 ..... Plastic Limit 35.6 .....
Date..... Plasticity Index 2.9 ..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L. L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	43		32		24		16		11	
Container No.....	143		172		173		175		157	
Wt of wet soil & container...g..	23.9		24.0		22.5		23.8		25.6	
Wt of dried soil & container g..	19.7		19.8		18.6		19.3		20.5	
Wt of container..... g...	8.4		8.4		8.3		8.1		8.5	
Wt of dry soil (Wd).....	11.3		11.4		10.3		11.2		12.0	
Wt of moisture (Wm/Wd) .....%	4.1		4.2		3.9		4.5		5.1	
Moisture content 100(Wm/Wd)...%	36.3		36.8		37.9		40.2		42.5	
Type of test						PL		PL		PL
No of blows/shrinkage %.....						-		-		-
Container No.....						177		149		140
Wt of wet soil & container... g..						11.8		12.1		12.2
Wt of dried soil & container...						11.0		11.3		11.3
Wt of container..... g ..						8.7		8.7		8.8
Wt of dry soil (Wd)						2.3		2.5		2.5
Wt of moisture (Wm)..... g ..						0.8		0.9		0.9
Moisute content 100(Wm/Wd)...%						34.8		36.0		36.0

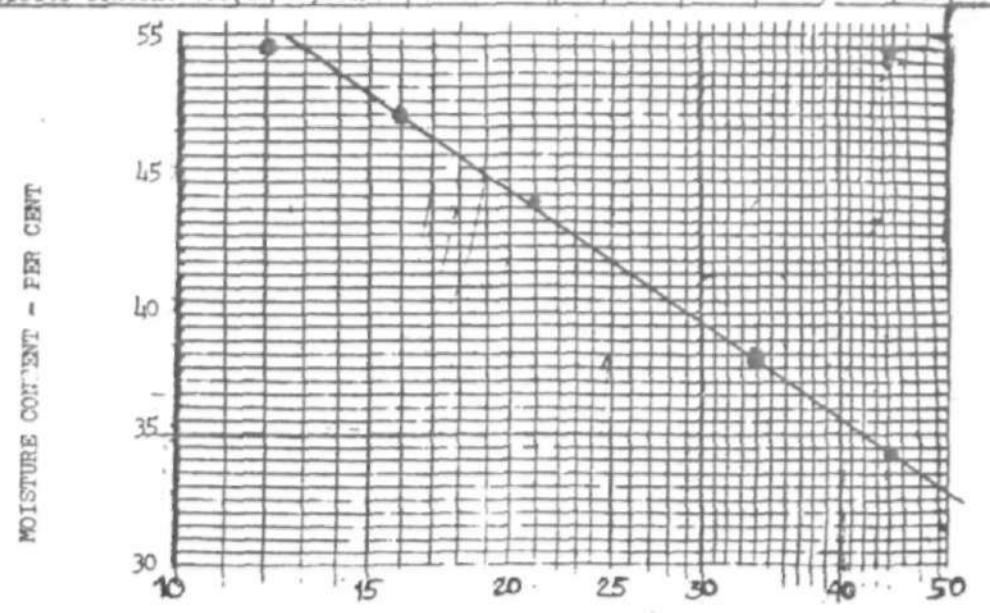


MATERIAL TEST 4% Cement (8gms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No..... Liquid Limit.39.7..... Plastic Limit.24.5.....
Date..... Plasticity Index...15.2..... Linear Shrinkage.....
Job..... Description of soil .....
Site.....
L.L. Machine No..... Operator
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	48	48	38		24		17.		11	
Container No.....	401	401	308		402		208		206	
Wt of Wet soil & container...g..	37.0	37.3	38.4		38.6		38.9		38.8	
Wt of dried soil & container g..	34.0	32.9	33.6		33.7		33.8		32.9	
Wt of container..... g..i		21.3	21.0		21.4		21.2		21.4	
Wt of dry soil (Wd).....		11.6	12.6		12.3		12.5		11.5	
Wt of moisture (Wm/Wd) .....%		4.4	4.8		4.9		5.1		5.9	
Moisture content 100(Wm/Wd)...%		37.8	38.0		39.8		40.8		43.3	
Type of test						PL		PL		PL
No of blows/shrinkage %.....						-		-		-
Container No.....						104		200		211
Wt of wet soil & container... g..						23.9		17.0		25.1
Wt of dried soil & container...						23.4		16.6		20.6
Wt of container..... g ..						21.2		14.9		20.6
Wt of dry soil (Wd)						2.2		1.7		2.0
Wt of moisture (Wm)..... g ..						0.5		0.4		0.5
Moisute content 100(Wm/Wd)...%						25.0		23.5		25

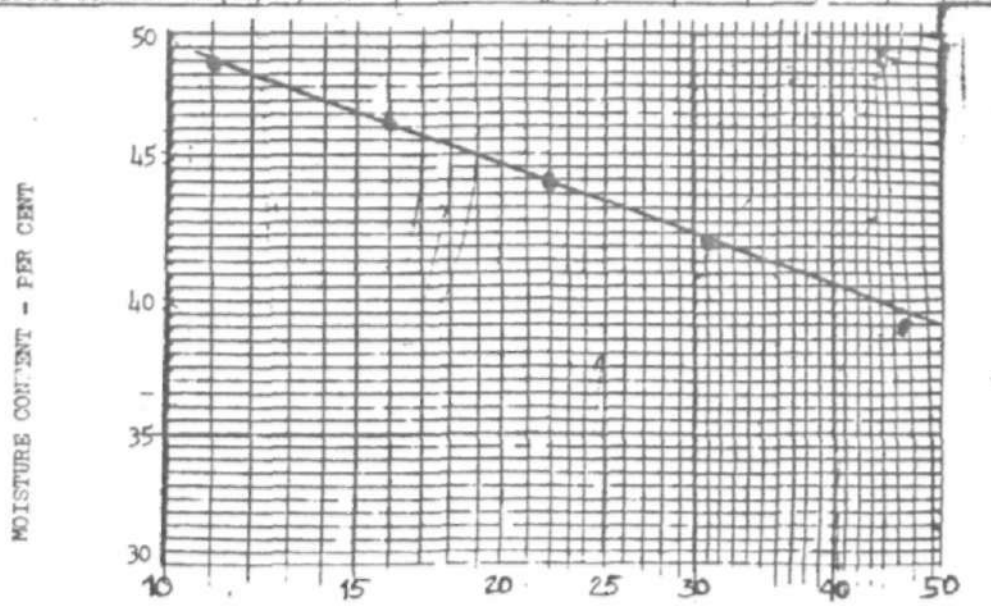


MATERIAL TEST 6% Cement (12 ms)

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No. - Liquid Limit 38.2 Plastic Limit 20.9
Date - Plasticity Index 17.3 Linear Shrinkage -
Job Project Description of soil
Site A. B. U. T. H. Shika
L. L. Machine No. - Operator Awaisu M. M.
Proportion of sample retained on No. 36 B.S. Sieve
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test	LL		LL		LL		LL		LL	
No of blows/shrinkage %	42		32		22		16		10	
Container No	404		109		205		44		204	
Wt of Wet soil & container...g..	39.0		37.0		37.8		39.0		40.0	
Wt of dried soil & container g..	34.2		32.4		33.1		34.0		33.9	
Wt of container g..	21.0		21.1		21.0		21.2		20.7	
Wt of dry soil (Wd)	13.2		11.3		12.1		12.8		13.2	
Wt of moisture (Wm/Wd) .....%	4.8		4.2		4.7		5.0		6.1	
Moisture content 100(Wm/Wd)...%	36.4		37.2		38.8		39.1		40.0	
Type of test						PL		PL		PL
No of blows/shrinkage %						-		-		-
Container No						310		407		406
Wt of wet soil & container... g..						24.4		24.3		24.0
Wt of dried soil & container...						23.8		23.7		23.4
Wt of container g..						20.9		20.8		20.6
Wt of dry soil (Wd)						2.9		2.9		2.8
Wt of moisture (Wm) g ..						0.6		0.6		0.6
Moisute content 100(Wm/Wd)...%						20.7		20.7		21.4

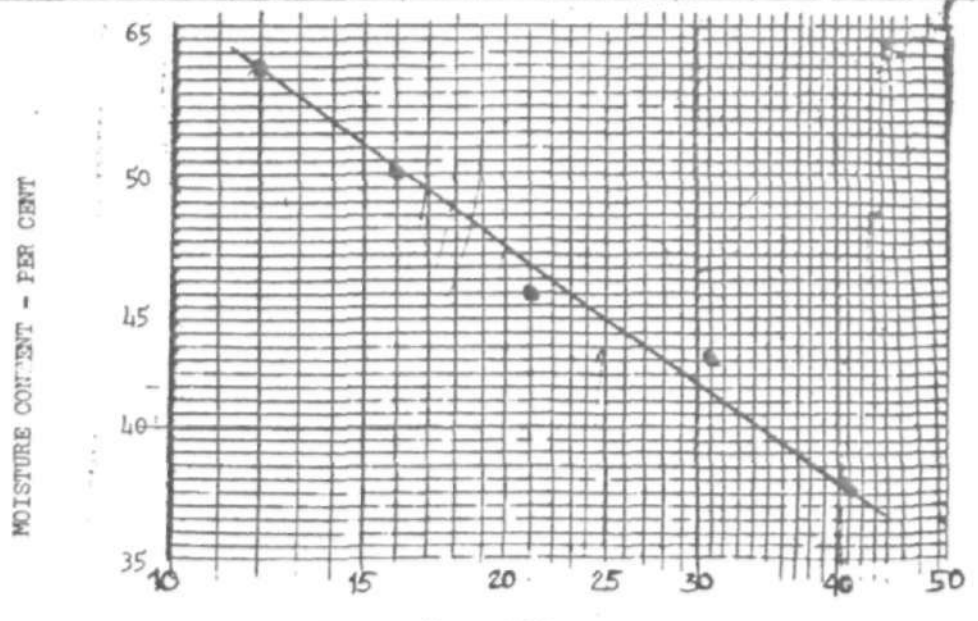


MATERIAL TEST 8% Cement

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE (16gms)

Sample No.....7..... Liquid Limit.....43..... Plastic Limit.....20.4.....
Date..... Plasticity Index.....22.6..... Linear Shrinkage.....
Job.....Project..... Description of soil .....
Site.....A. B. U. T. E. Shika.....
L.L. Machine No..... Operator Awaisu M. M.
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	48		38		21		19		14	
Container No.....	302		202		301		209		203	
Wt of Wet soil & container...g..	39.0		38.3		36.2		37.8		38.6	
Wt of dried soil & container g..	34.0		33.4		31.5		32.6		33.0	
Wt of container..... g...	20.8		21.1		20.3		20.8		21.1	
Wt of dry soil (Wd).....	13.2		12.3		11.2		11.8		11.9	
Wt of moisture (Wm/Wd) .....%	5.0		4.9		4.7		5.2		5.6	
Moisture content 100(Wm/Wd)...%	37.9		39.8		42.0		44.1		47.1	
Type of test						PL		PL		PL
No of blows/shrinkage %.....						-		-		-
Container No.....						306		408		207
Wt of wet soil & container... g..						25.0		19.5		25.1
Wt of dried soil & container...						24.3		18.7		24.4
Wt of container..... g ..						20.8		14.9		20.9
Wt of dry soil (Wd)						3.5		3.8		3.5
Wt of moisture (Wm)..... g ..						0.7		0.8		0.7
Moisute content 100(Wm/Wd)...%						20.0		21.1		20.0

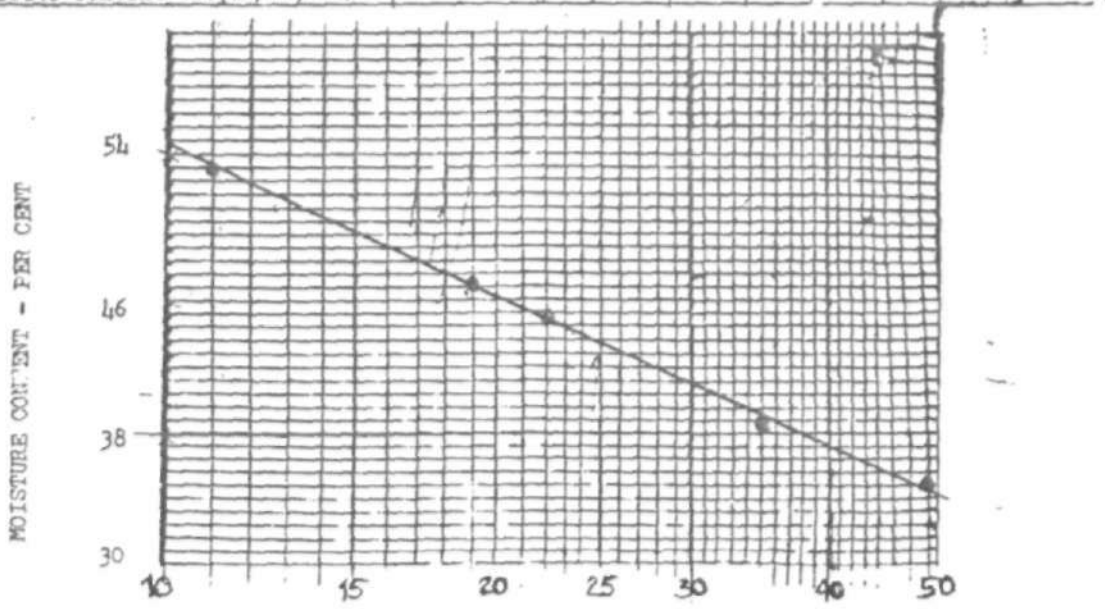


MATERIAL TEST 10% Cement

LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE (m20gms)

Sample No..... Liquid Limit 40 Plastic Limit 23.80
Date..... Plasticity Index 16.2 Linear Shrinkage -
Job Project Description of soil -
Site A. B. U. T. H. Shika
L. L. Machine No..... Operator AWAISU M. M.
Proportion of sample retained on No. 36 B.S. Sieve .....
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear shrinkage.
Liquid limit marked L.L. Plastic limit marked P.L. Linear shrinkage marks

Type of test.....	LL		LL		LL		LL		LL	
No of blows/shrinkage %....	45		32		21		16		11	
Container No.....	107		208		213		201		307	
Wt of Wet soil & container...g..	37.8		37.8		36.0		39.1		36.4	
Wt of dried soil & container g..	33.3		32.9		31.6		33.7		31.4	
Wt of container..... g...	21.0		20.4		20.7		20.6		21.1	
Wt of dry soil (Wd).....	12.8		12.5		10.9		13.1		10.3	
Wt of moisture (Wm/Wd) .....%	4.5		4.9		4.4		5.4		5.0	
Moisture content 100(Wm/Wd)...%	36.6		39.2		40.4		41.2		43.5	
Type of test						PL		PL		PL
No of blows/shrinkage %.....						-		-		-
Container No.....						309		205		304
Wt of wet soil & container... g..						25.0		24.2		25
Wt of dried soil & container...						24.3		23.5		24.2
Wt of container..... g ..						21.3		20.4		20.9
Wt of dry soil (Wd)						3.0		3.1		3.3
Wt of moisture (Wm)..... g ..						0.7		0.70		0.8
Moisute content 100(Wm/Wd)...%						23.3		22.6		24.2



APPENDIX C

RESULTS OF STANDARD PROCTOR COMPACTION TEST ON THE SOIL - STABILIZERS.

FORM F 2% lime

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job. M.Sc PROJECT Sample No. / Operator M.M. AWAISH

Site. ABU TW SHEA Depth. Date.

Amount retained on 3/4" B.S. Sieve .....g. Total weight of sample.....g.

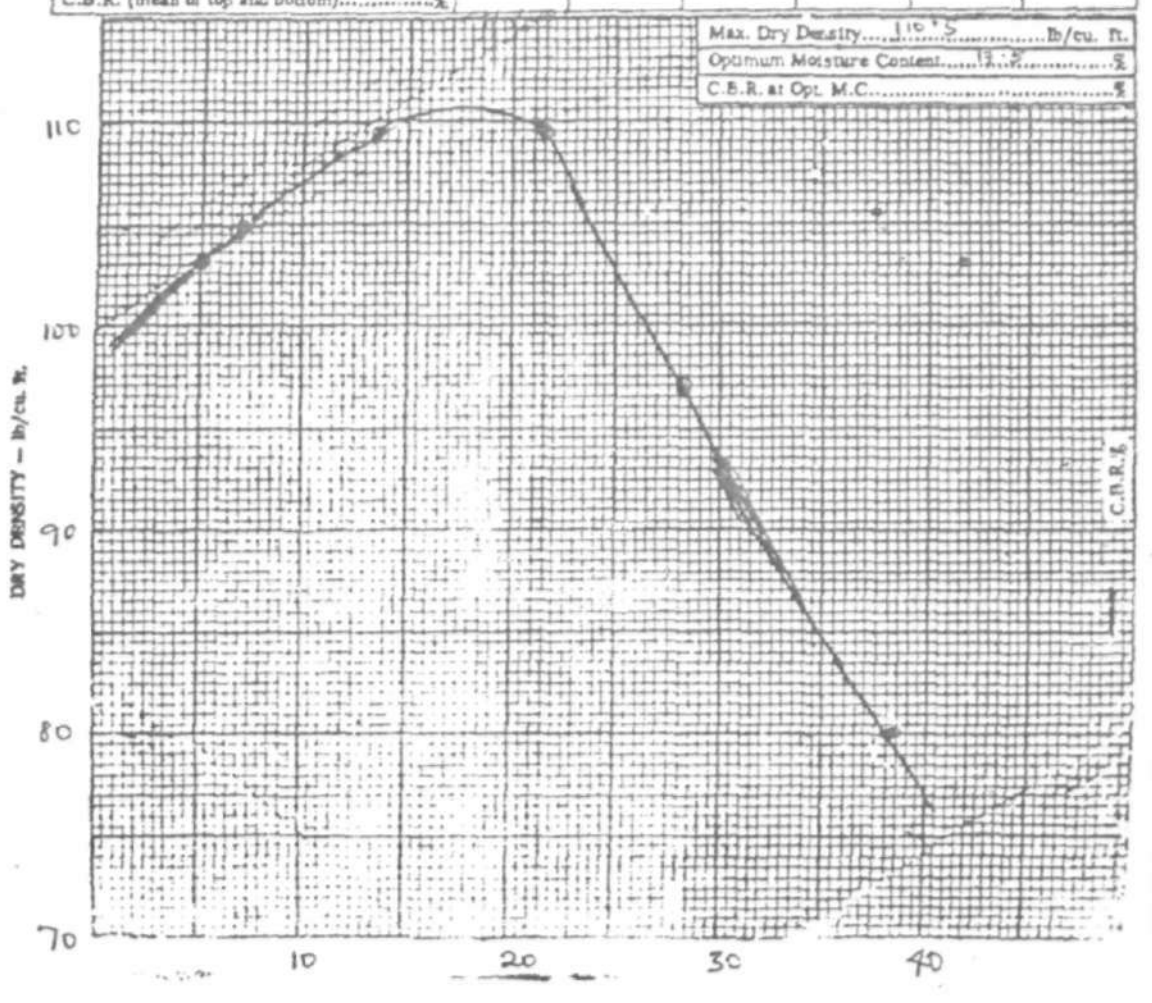
B.S.*/C.B.R.* Mould. *Delete the inappropriate word

Wt. of mould and wet soil (W2) g.	6050	6110	6300	6430	6350	6100	
Wt. of mould (W1) g.	4420	4420	4420	4420	4420	4420	
Wt. of wet soil (W2 - W1) g.	1630	1690	1880	2010	1880	1680	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$ lb/cu. ft.	107.89	111.77	124.34	132.94	124.33	111.11	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.	125	133	145	163	193	164	131	137	178	179	161	151
Wt. of wet soil and container g.	42.3	45.2	49.5	49.2	44.7	41.9	44.3	48.0	59.7	59.0	66.5	81.6
Wt. of dry soil and container g.	40.7	43.3	47.4	46.7	40.3	38.0	38.2	40.9	48.6	48.0	50.2	61.4
Wt. of container g.	8.7	8.7	8.8	8.8	8.7	8.3	8.8	8.6	8.7	8.9	8.5	8.9
Wt. of dry soil (Ws) g.	32	34.6	38.6	37.9	31.6	29.7	29.4	32.3	39.9	39.1	41.7	52.5
Wt. of moisture (Ww) g.	1.60	1.90	2.50	2.70	4.4	3.9	6.1	7.1	11.1	11.0	16.3	20.2
Moisture content 100 Ww/Ws %	5.00	5.49	6.48	7.12	13.92	13.13	20.75	21.98	27.82	28.13	39.09	38.48
Average moisture content (m) %	5.25		6.80		13.53		21.37		27.98		38.79	
Dry density $\gamma d = 100\gamma/100+m$ lb/cu. ft.	102.42		104.65		109.52		109.53		97.15		80.06	
C.B.R. (mean of top and bottom) %												



FORM K ..... 4% lime .....

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job..... M.Sc PROJECT ..... Sample No..... / ..... Operator..... M.M. AWAD .....

Site..... ABUTH SAMKA ..... Depth..... Date.....

Amount retained on 3/4" B.S. Sieve.....g..... Total weight of sample.....g.....

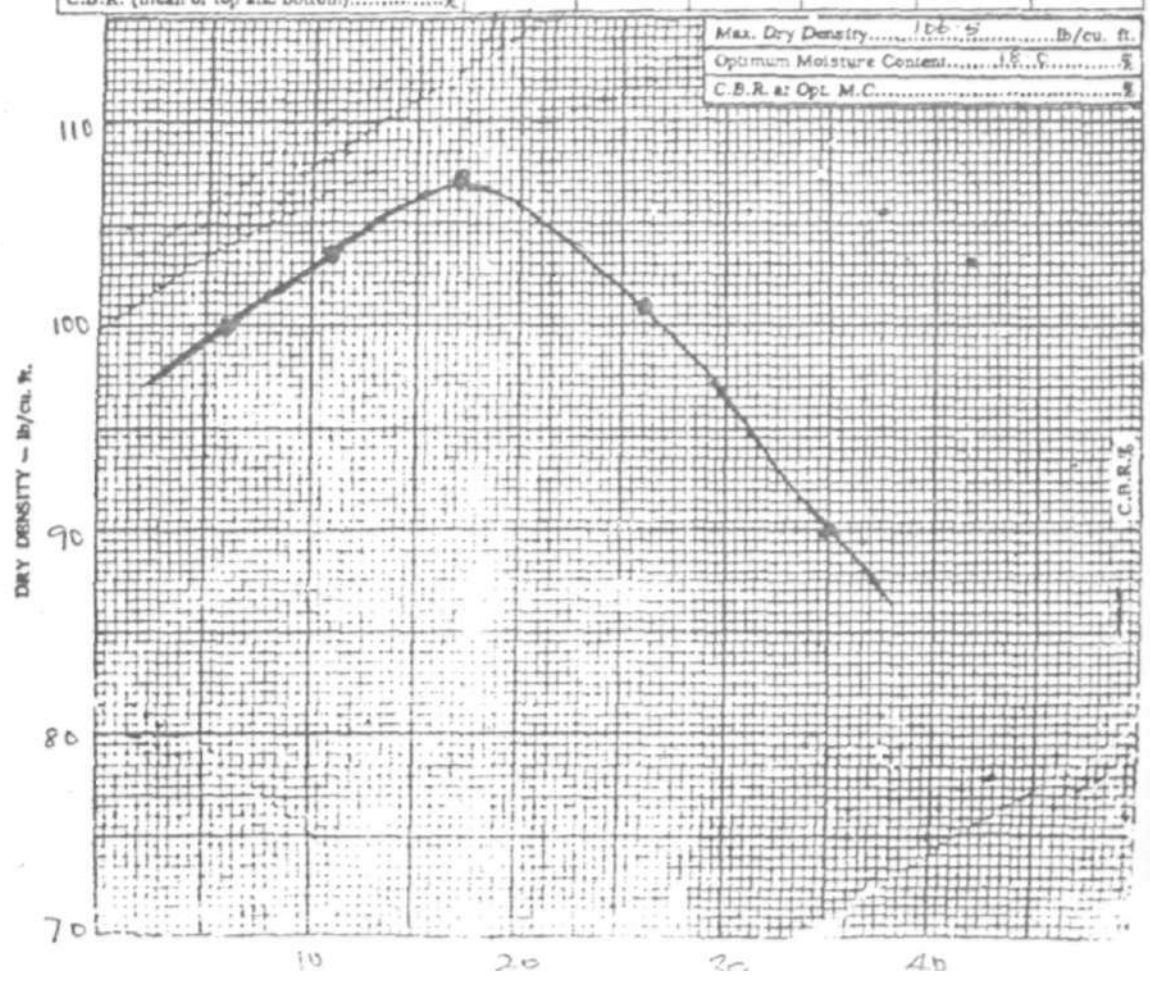
B.S.*/C.B.R.* Mould..... *Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	6060	6120	6360	6345	6255		
Wt. of mould.....(W1).....g	4420	4420	4420	4420	4420		
Wt. of wet soil.....(W2 - W1).....g	1640	1700	1940	1925	1835		
Bulk density $\gamma = \frac{W_2 - W_1}{X}$ .....lb/cu. ft.	108·47	112·43	128·31	127·31	121·36		

For B.S. Mould X = 15.12 *For C.B.R. Mould X = 37.11*

MOISTURE CONTENT DETERMINATIONS

Container No.....	172	71	34	178	36	43	32	12	74	1		
Wt. of wet soil and container.....g	48·2	51·2	57·4	51·3	43·8	53·9	49·2	49·6	64·2	56·55		
Wt. of dry soil and container.....g	46·0	48·6	49·2	47·5	38·7	46·6	37·2	41·2	50·2	44·3		
Wt. of container.....g	8·6	9·2	9·0	8·9	9·0	9·1	9·2	9·2	9·4	9·3		
Wt. of dry soil (Ws).....g	37·4	39·4	40·2	38·6	29·7	37·5	28·0	32·0	40·8	35·0		
Wt. of moisture (Ww).....g	2·2	2·6	4·8	3·8	5·1	6·3	7·0	8·4	14·0	12·25		
Moisture content 100 Ww/Ws.....%	5·88	6·68	11·94	9·84	17·17	16·80	25·0	26·25	34·31	35		
Average moisture content (m).....%	6·28		10·89		16·99.		25·63		34·66			
Dry density $\gamma_d = 100\gamma/100+m$.....lb/cu. ft.	100·06		101·39		106·50		101·4		90·12			
C.B.R. (mean of top and bottom).....%												



FORM K 6% lime

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL
USING STANDARD*/HEAVY* COMPACTION

Job. M.Sc PROJECT Sample No. / Operator M. M. AWANSU

Site. ABUTH SHIRA ..... 1.98.M. Date.....

Amount retained on 3/4" B.S. Sieve .....g. Total weight of sample.....g.

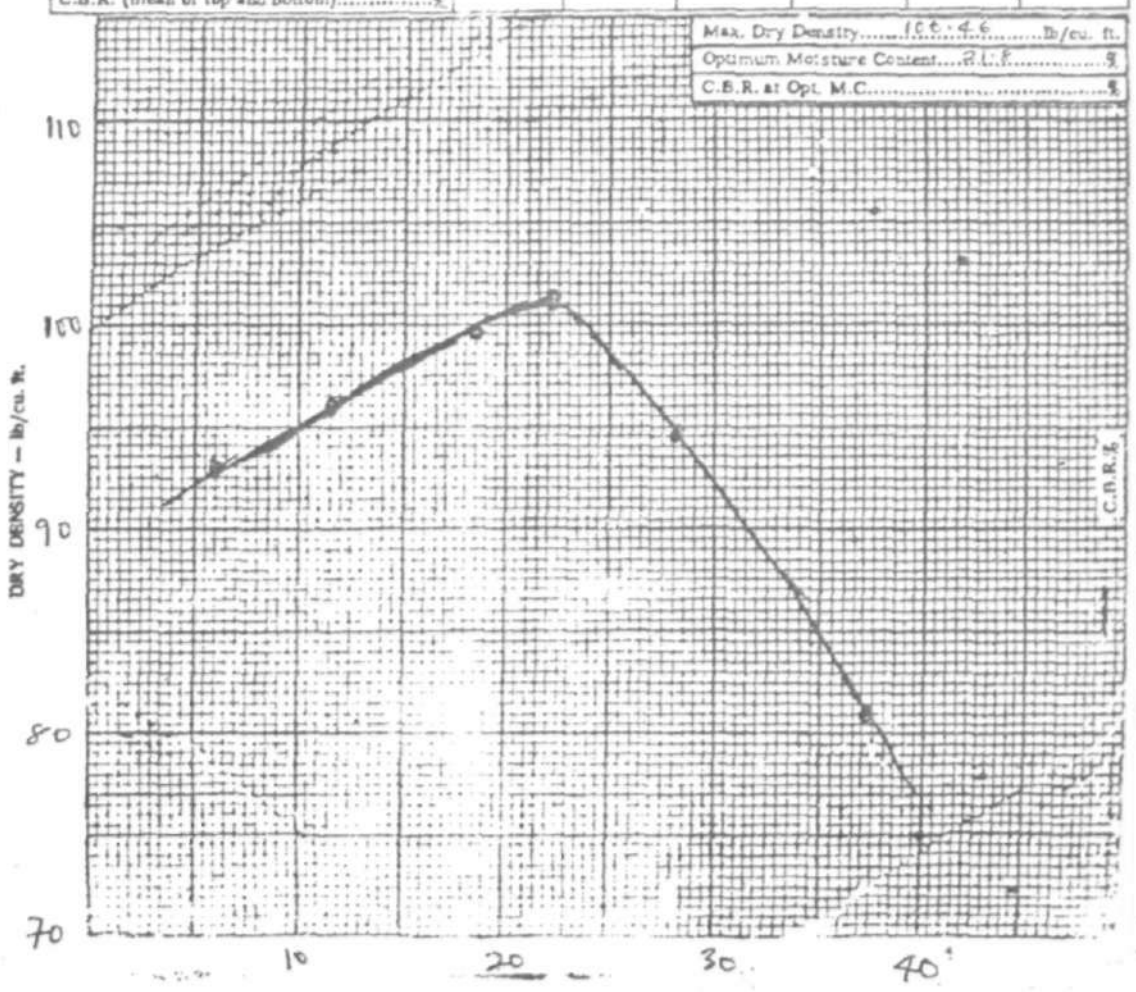
B.S.*/C.B.R.* Mould..... *Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	5565	5660	5830	5510	5870	5730	
Wt. of mould.....(W1).....g	4050	4050	4050	4050	4050	4050	
Wt. of wet soil.....(W2 - W1).....g	1515	1610	1780	1850	1820	1680	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft	100.20	106.48	117.73	122.35	120.37	111.11	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.	3	4	5	2	P	16	11	17	12	19	20	C
Wt. of wet soil and container.....g	51.4	56.3	58.9	58.9	58.7	56.8	55.8	53.4	67.8	69.6	62.6	72.7
Wt. of dry soil and container.....g	49.9	54.3	54.9	55.0	52.9	51.1	49.4	47.8	52.2	58.6	51.9	58.4
Wt. of container.....g	21.1	20.6	20.5	21.5	21.2	20.8	21.1	21.0	20.7	20.9	20.9	20.4
Wt. of dry soil (Wd).....g	28.8	33.6	34.4	33.5	31.7	30.3	28.3	26.8	36.5	37.7	30.5	38.0
Wt. of moisture (Ww).....g	1.5	2.0	4	3.5	5.8	5.7	7.4	5.6	10.6	10.4	11.2	14.3
Moisture content 100 Ww/Ws.....%	5.2	5.9	11.6	11.6	18.3	18.8	22.6	20.9	29.1	27.8	36.7	37.6
Average moisture content (m).....%	6.1		11.6		18.6.		21.8		28.4		37.2	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu.ft	99.44		95.41		99.26		100.46		93.73		80.98	
C.B.R. (mean of top and bottom).....%												



FORM F 8% lime

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job...M.Sc. PROJECT.....Sample No.....Operator...AWASU M.M

Site...ABUTH SHIKPA.....Depth.....1.98 M.....Date.....

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....200.....g.....

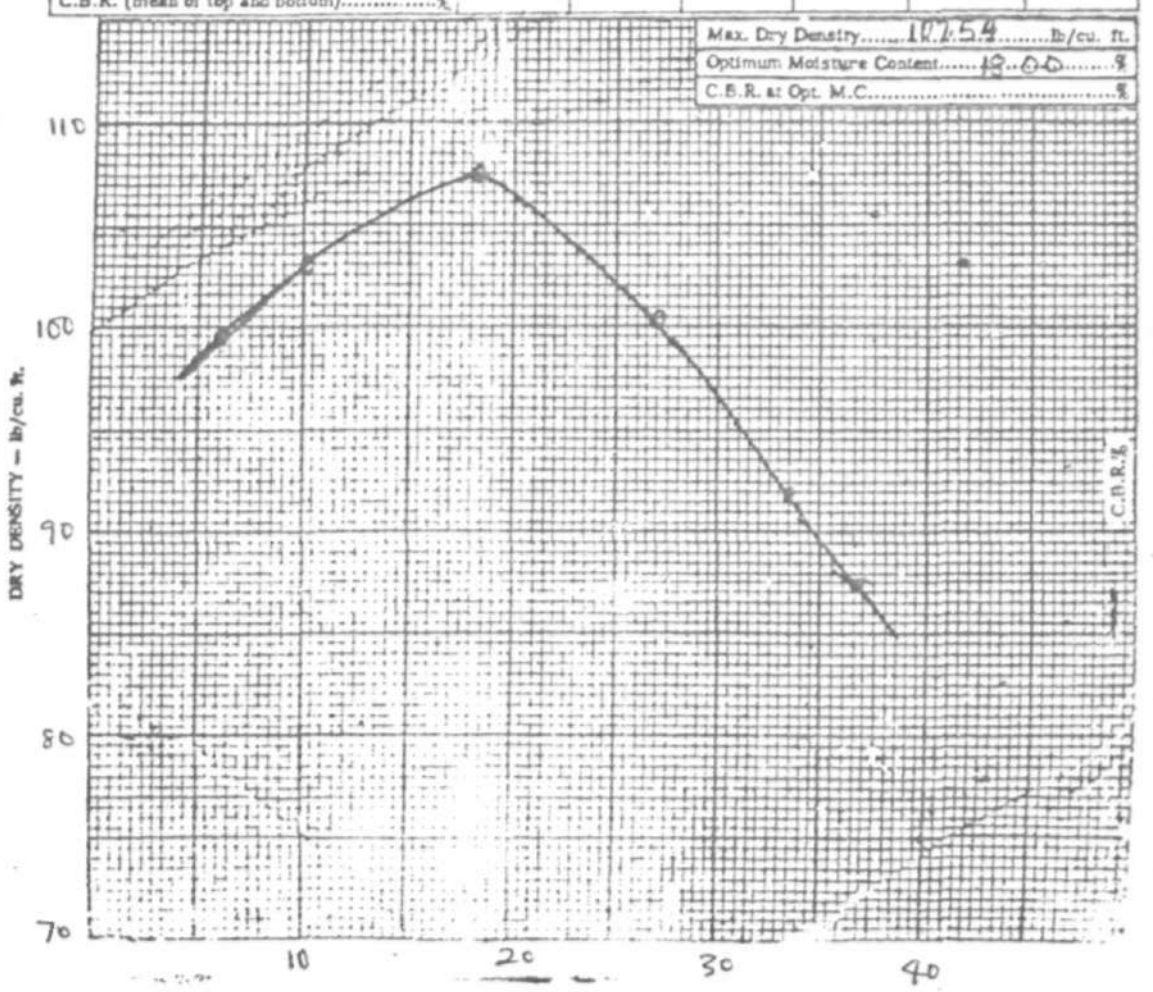
B.S.*/C.B.R.* Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....	6810	6150	6340	6350	6280	6230	
Wt. of mould.....(W1).....	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1).....g....	1590	1730	1920	1930	1860	1810	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	105.16	114.47	126.98	127.65	123.02	119.71	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	12	2	32	30	46	51	178	43	29	66	39	34
Wt. of wet soil and container.....g....	50.0	50.8	47.2	55.2	48.6	45.0	36.0	37.9	53.0	65.3	62.7	62.0
Wt. of dry soil and container.....g....	49.5	48.2	43.7	51.0	42.9	39.2	30.2	31.3	41.9	51.9	48.6	47.4
Wt. of container.....g....	8.8	9.0	5.0	9.1	8.6	9.5	8.6	9.0	8.9	9.4	9.1	8.9
Wt. of dry soil (Ws).....g....	40.7	39.2	34.7	41.9	34.3	29.7	21.6	22.3	33.0	42.0	39.5	38.5
Wt. of moisture (Ww).....g....	2.5	2.6	3.5	4.2	5.7	5.8	5.5	6.1	11.1	13.9	14.1	14.6
Moisture content 100 Ww/Ws.....%	6.14	6.63	10.09	10.02	16.62	19.57	26.85	27.25	33.64	33.10	35.70	37.9
Average moisture content (m).....%	6.39		10.06		18.08.		27.10		33.37		36.81	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft.	98.84		103.96		107.54		100.43		92.29		87.50	
C.B.R. (mean of top and bottom).....%												



FORM K 10% lime

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job M.Sc Project Sample No. / Operator M. M. AWANSY

Site ABUTH SHIKA Depth 1.98 m Date

Amount retained on 3/4" B.S. Sieve .....g.....Total weight of sample.....g.....

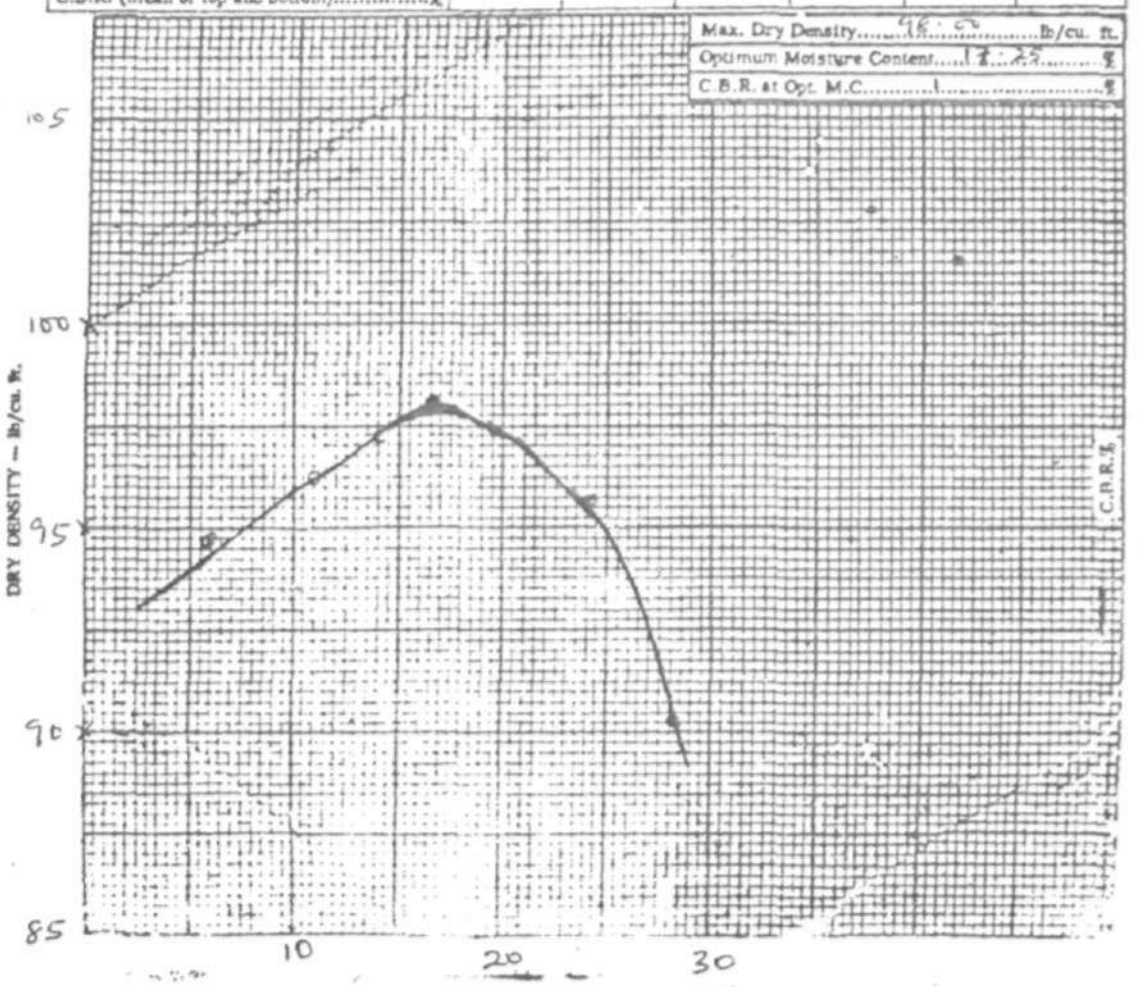
B.S.*/C.B.R.* Mould..... *Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....	5580	5665	5730	5710	5850	5800	
Wt. of mould.....(W1).....	4050	4050	4050	4050	4050	4050	
Wt. of wet soil.....(W2 - W1).....	1530	1615	1680	1738	1800	1750	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	101·19	106·81	111·11	114·91	119·05	115·74	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	158	168	129	143	173	175	164	177	163	151	180	172
Wt. of wet soil and container.....g....	35·45	38·76	48·4	45·0	45·5	43·5	42·0	42·5	47·1	47·4	43·8	42·76
Wt. of dry soil and container.....g....	37·8	36·80	44·5	41·4	40·8	39·8	37·20	37·7	39·6	39·7	36·1	35·5
Wt. of container.....g....	8·9	8·7	9·6	8·9	8·7	8·6	8·7	8·8	8·8	8·9	9·1	8·9
Wt. of dry soil (Ws).....g....	28·9	28·1	35·5	32·5	32·1	31·2	28·5	28·9	30·8	30·8	27	27·8
Wt. of moisture (Ww).....g....	1·7	1·9	3·9	3·60	5·1	4·1	4·8	5·1	7·5	7·3	7·7	7·2
Moisture content 100 Ww/Ws.....%	5·88	6·76	11·0	11·0	15·89	13·14	16·84	17·65	24·35	24·35	28·52	27·8
Average moisture content (m).....%	6·32		11·50		14·52		17·25		24·03		27·80	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft.	95·17		96·23		97·62		98·06		95·98		96·56	
C.B.R. (mean of top and bottom).....%												



FORM F ....0%.... (CONTROL)....

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL
USING STANDARD*/HEAVY* COMPACTION

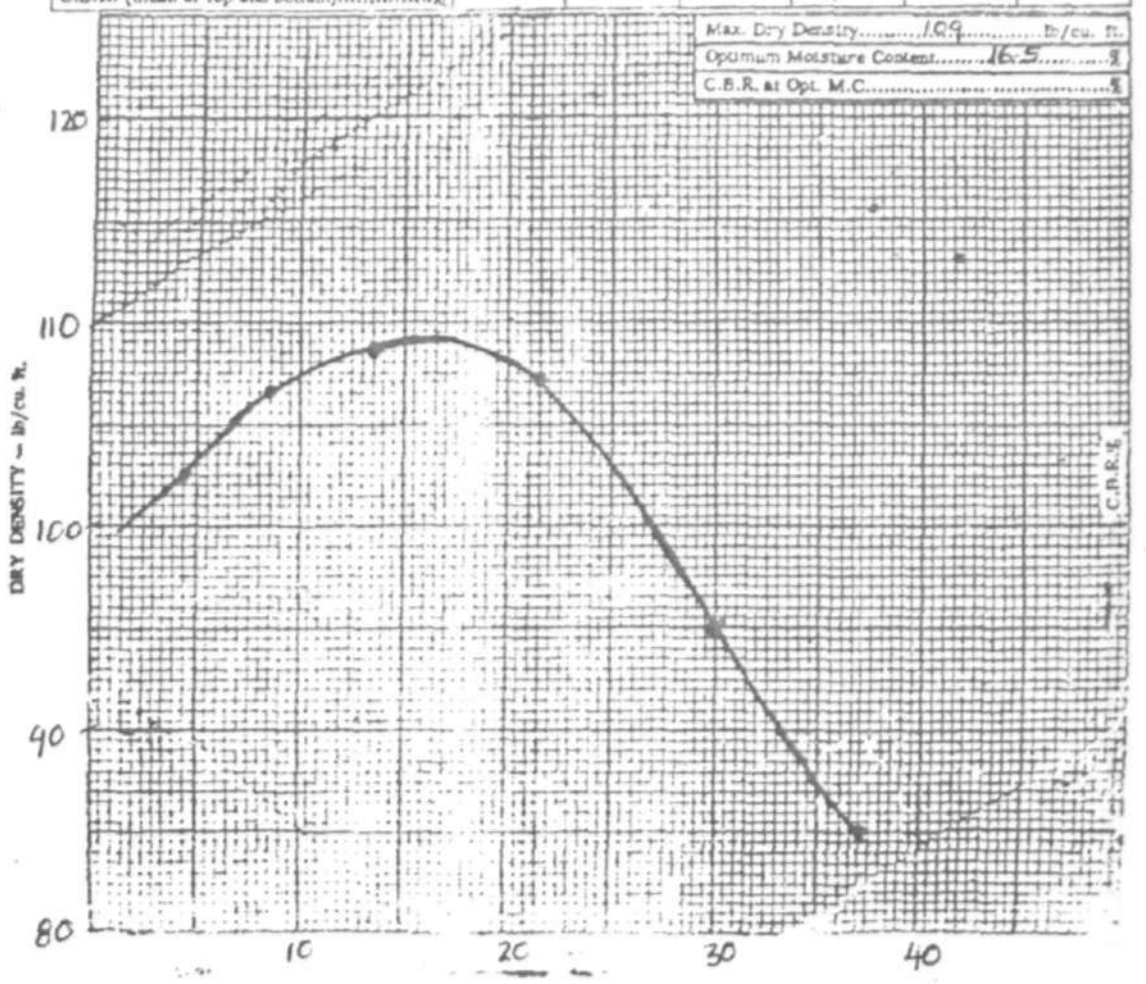
Job..M.Sc. Project.....Sample No.....Operator..Awnsu M.M.
Site..ABU.TH....SHIKA.....Depth.....1.98 m.....Date.....
Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....g.....
B.S.*/C.B.R.* Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2)	6120	6180	6280	6400	6290	6180	
Wt. of mould.....(W1)	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1)	1700	1760	1860	1980	1870	1760	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$ .....lb/cu. ft.	112.43	116.40	123.02	130.95	123.68	116.40	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	30	52	39	164	42	44	163	161	179	35	48	193
Wt. of wet soil and container.....g	42.8	41.1	50.0	43.9	41.3	46.3	59.2	51.5	64.9	71.5	73.9	70.2
Wt. of dry soil and container.....g	41.1	40.0	47.0	41.0	37.5	35.8	49.8	43.8	51.7	57.5	57.3	58.8
Wt. of container.....g	8.9	9.3	9.5	8.0	5.2	9.2	8.7	8.7	8.8	9.2	9.5	8.7
Wt. of dry soil (Ws).....g	32.2	30.7	37.5	33.0	32.3	26.6	41.1	35.1	42.5	48.3	48.6	45.1
Wt. of moisture (Wm).....g	1.7	1.1	3.0	2.9	3.4	4.2	9.4	7.7	13.2	14.0	17.6	16.4
Moisture content 100 Wm/Ws.....%	5.28	3.58	8.00	8.78	10.58	15.78	22.9	21.9	31.1	29.0	37.8	36.4
Average moisture content (m).....%	4.43		8.39		13.16		22.41		30.03		37.07	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft	107.66		107.39		108.71		106.98		95.12		84.92	
C.B.R. (mean of top and bottom).....%												



FORM F ...2%...Bullet - Scales.

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job..M.Sc. PROJECT.....Sample No.....Operator..M.M. ANAFUSY

Site..ABUTH.....ZARIA..Depth.....1:98.m.....Date.....

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample..3000.....g.....

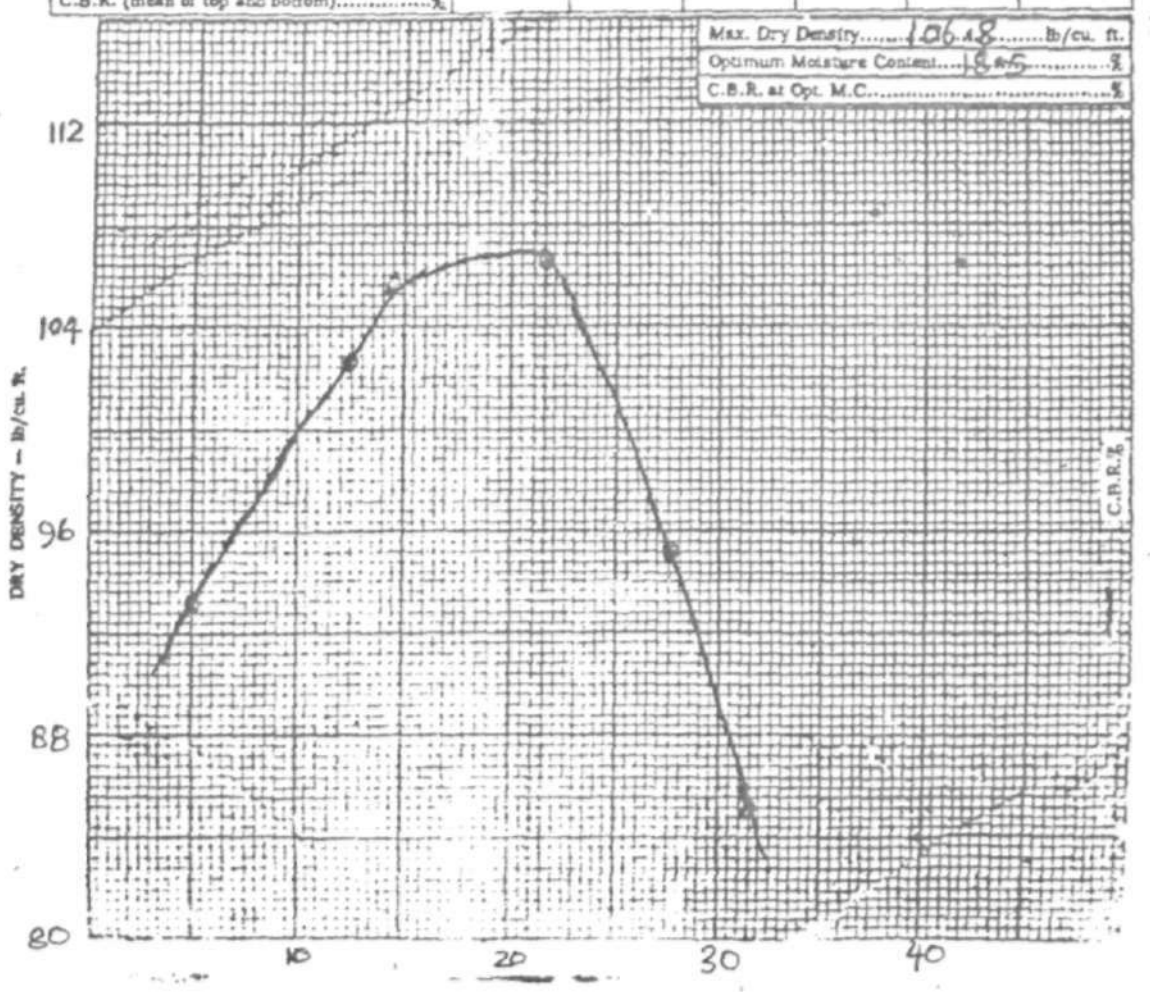
B.S.*/~~C.B.R.* Mould~~ *Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....	5530	5680	5880	5940	5880	5730	
Wt. of mould.....(W1).....	4050	4050	4050	4050	4050	4050	
Wt. of wet soil.....(W2 - W1).....g....	1480	1630	1830	1940	1830	1680	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	97.88	107.80	21 03	128.31	121.03	111.11	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	173	151	27	58	46	34	11	15	52	40	74	55
Wt. of wet soil and container.....g....	47.3	42.2	38.8	43.:	43.4	43.3	44.5	45.8	38.4	39.0	53.7	61.6
Wt. of dry soil and container.....g....	45.6	41.3	35.4	39.1	39.0	39.0	38.9	39.5	32.1	32.7	43.3	45.3
Wt. of container.....g....	8.6	8.5	9.1	9.0	8.8	8.9	9.3	9.0	9.2	9.6	8.9	8.8
Wt. of dry soil (Ws).....g....	37.0	32.8	26.3	30.1	30.2	30.1	29.6	30.5	22.9	23.1	34.4	40.5
Wt. of moisture (Ww).....g....	1.9	1.6	3.4	3.9	4.4	4.3	5.5	6.3	6.3	6.3	10.4	12.3
Moisture content 100 Ww/Ws.....%	4.9	4.9	12.9	13.0	14.6	14.1	18.8	20.7	27.5	27.3	30.2	30.4
Average moisture content (m).....%	4.9		13.0		14.4		20.3		27.4		30.3	
Dry density $\gamma_d = 100\gamma/100+m$.....lb/cu. ft.	93.33		98.40		105.80		106.66		95.00		85.27	
C.B.R. (mean of top and bottom).....%												



FORM K 4"/R Billet - Scales

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job. MSA PROJECT Sample No. / Operator. M.M. ALHAISU

Site. ABUJA STRATA Depth. 1:98 M Date.

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....g.....

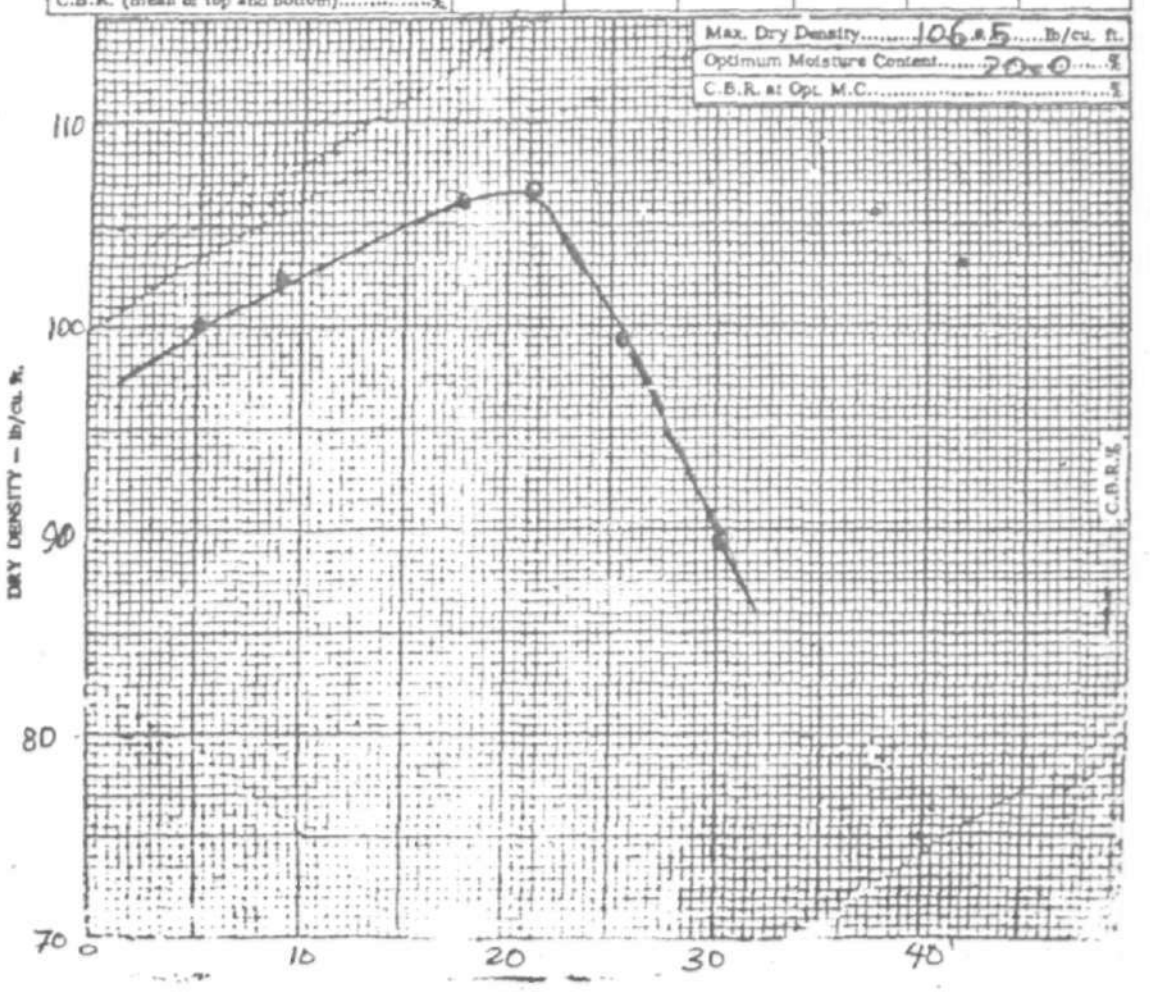
B.S.*/~~C.B.R.*~~ Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2)	5840	5727	5935	6020	5910	5815	
Wt. of mould.....(W1)	4050	4050	4050	4050	4050	4050	
Wt. of wet soil.....(W2 - W1)	1590	1677	1885	1970	1860	1765	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$ .....lb/	105.16	110.91	124.67	130.29	123.02	116.73	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.	46	27	0	58	170	164	405	206	200	305	208	107
Wt. of wet soil and container.....g	48.6	40.2	53.3	50.1	33.6	44.9	51.3	54.2	51.3	60.4	55.8	61.8
Wt. of dry soil and container.....g	46.50	38.8	49.2	47.2	29.6	39.6	45.0	48.5	42.8	52.2	50.2	52.6
Wt. of container.....g	8.6	8.7	9.0	8.6	8.3	8.3	14.9	21.4	14.8	21.3	20.6	21.0
Wt. of dry soil (Ws).....g	37.9	30.1	40.2	38.6	21.3	31.3	30.1	27.0	28.0	30.9	29.6	31.6
Wt. of moisture (Ww).....g	2.1	1.4	4.1	2.9	4.0	5.6	6.3	5.7	7.2	8.2	9.6	8.9
Moisture content 100 Ww/Ws.....%	5.5	4.7	10.2	7.5	18.8	16.9	20.9	21.1	25.7	26.5	32.4	28.2
Average moisture content (m).....%	5.1		8.9		17.9		21.0		26.1		30.3	
Dry density $\gamma_d = 100\gamma/100+m$.....lb/cu. ft.	100.06		101.82		105.74		106.58		97.56		89.59	
C.B.R. (mean of top and bottom).....%												



FORM K 5% Billet-Scales

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job...M.S.P. PROJECT.....Sample No.....—.....Operator.M.M. AWAISU

Site...ABUTH....ZARIA.....Depth.....1.98.....Date.....

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....—.....g.....

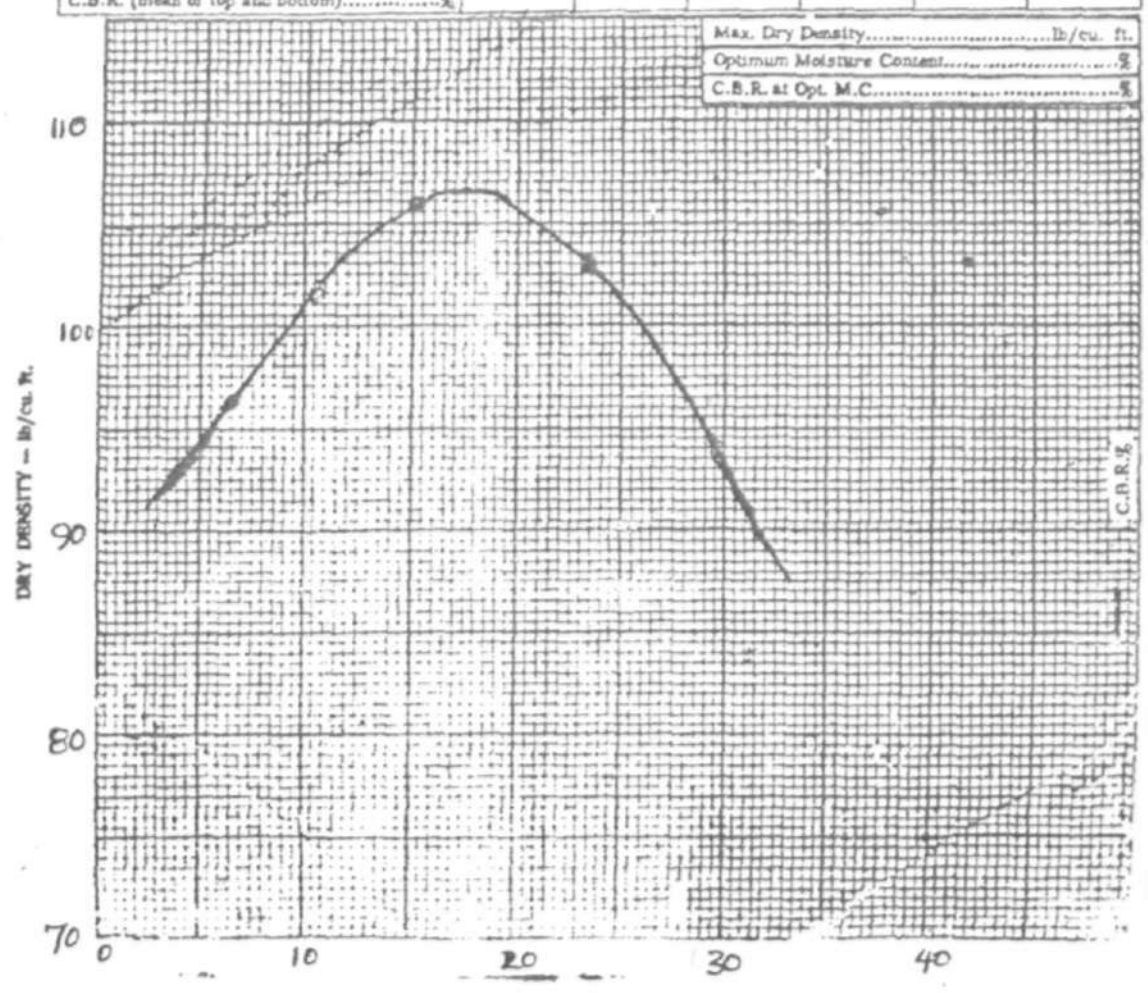
B.S.*/~~C.B.R.*~~ Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g....	5590	5750	6010	5960	5880		
Wt. of mould.....(W1).....g....	4050	4050	4050	4050	4050		
Wt. of wet soil.....(W2 - W1).....g....	1540	1700	1960	1910	1830		
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	101.85	112.43	129.63	126.32	121.03		

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	605	205	209	7	206	9	309	44	301	211		
Wt. of wet soil and container.....g....	534	515	504	521	560	501	651	592	611	580		
Wt. of dry soil and container.....g....	515	446	477	491	515	464	570	521	516	497		
Wt. of container.....g....	204	210	208	211	214	218	214	213	204	203		
Wt. of dry soil (Ws).....g....	311	286	269	279	301	252	356	308	312	294		
Wt. of moisture (Ww).....g....	19	19	27	31	45	37	81	71	95	83		
Moisture content 100 Ww/Ws.....%	6.1	6.6	10.0	11.1	15.0	14.7	22.8	23.1	30.4	28.2		
Average moisture content (m).....%	6.4		10.6		14.9		23.0		29.3			
Dry density $\gamma_d = 100\gamma/100+m$.....lb/cu. ft.	95.73		101.66		112.62		102.70		93.61			
C.B.R. (mean of top and bottom).....%												



FORM X — B.%... Bullet - scales.....

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job..M.SC. PROJECT.....Sample No.....7.....Operator..M.M. AWAISU

Site..ABUTH.....SIIKA.....Depth.....1:98.....Date.....

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....g.....

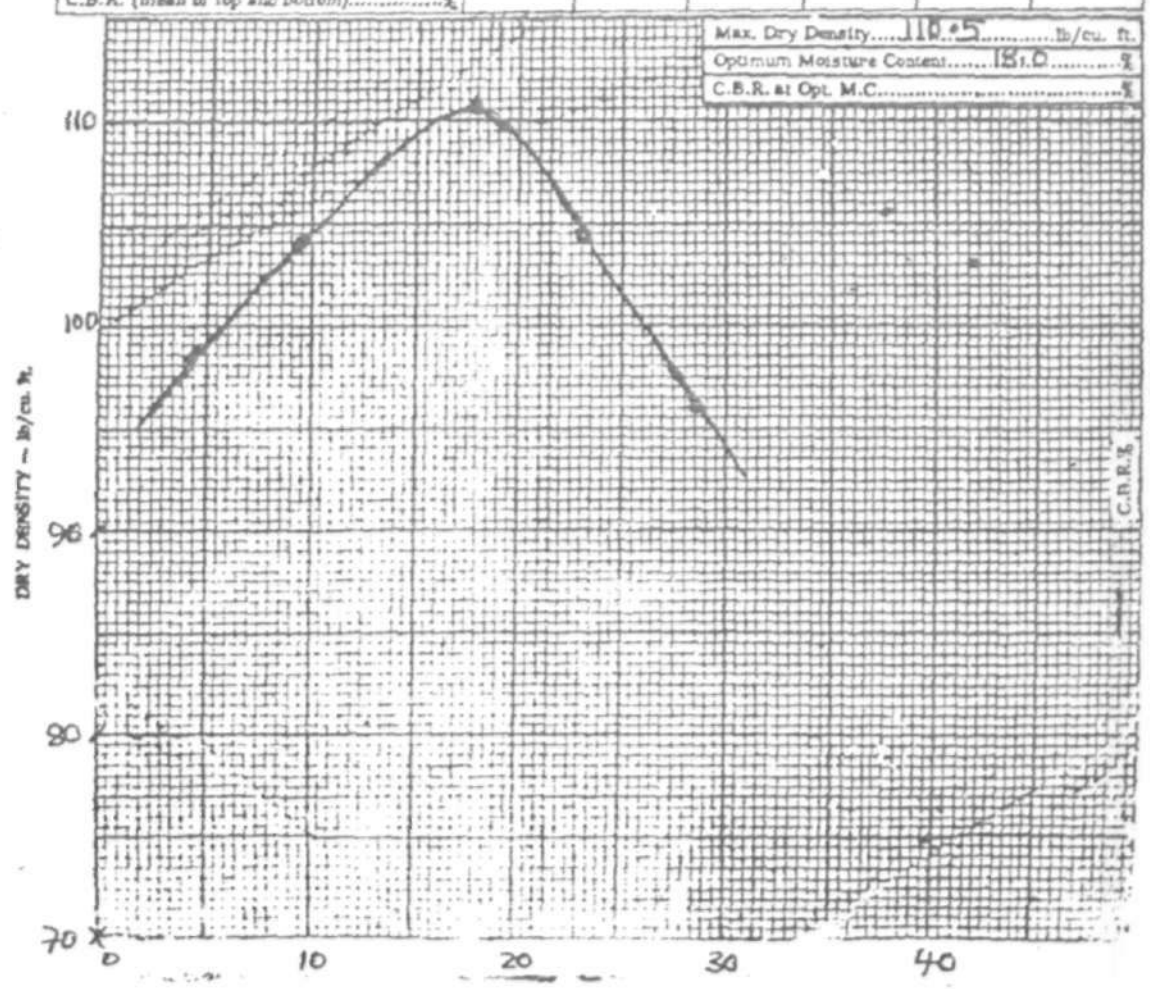
B.S.*/~~C.B.R.*~~ Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	5605	5780	6040	5965	5910		
Wt. of mould.....(W1).....g	4050	4050	4050	4050	4050		
Wt. of wet soil.....(W2 - W1).....g	1555	1730	1990	1915	1860		
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	102·84	114·42	131·61	126·65	123·02		

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	404	203	308	302	407	403	107	304	402	109		
Wt. of wet soil and container.....g	56·9	56·0	52·2	58·3	58·3	48·9	61·6	69·4	77·9	76·8		
Wt. of dry soil and container.....g	55·0	54·9	49·7	54·8	52·1	44·2	54·3	60·2	65·7	64·3		
Wt. of container.....g	20·3	21·2	21·1	20·9	20·9	14·9	21·1	20·9	20·9	21·2		
Wt. of dry soil (Ws).....g	34·7	33·7	28·6	33·9	31·2	29·3	33·2	39·1	45·3	43·1		
Wt. of moisture (Ww).....g	1·9	1·1	2·5	3·5	6·2	4·7	7·3	9·4	12·2	12·5		
Moisture content 100 Ww/Ws.....%	55	3·3	8·7	10·3	19·9	16·0	22·0	24·0	26·9	29·0		
Average moisture content (m).....%	4·4		9·5		18·0		23·0		28·0			
Dry density $\gamma_d = 100\gamma/100+m$.....lb/cu. ft.	98·51		104·9		110·53		102·97		96·11			
C.B.R. (mean of top and bottom).....%												



FORM * 10% Billet - Scales

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job..M.Sc...PROJECT.....Sample No.....Operator..M.M. AWAISU

Site...ABUTH.....SHIKA.....Depth.....1.2.6.....Date.....

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....g.....

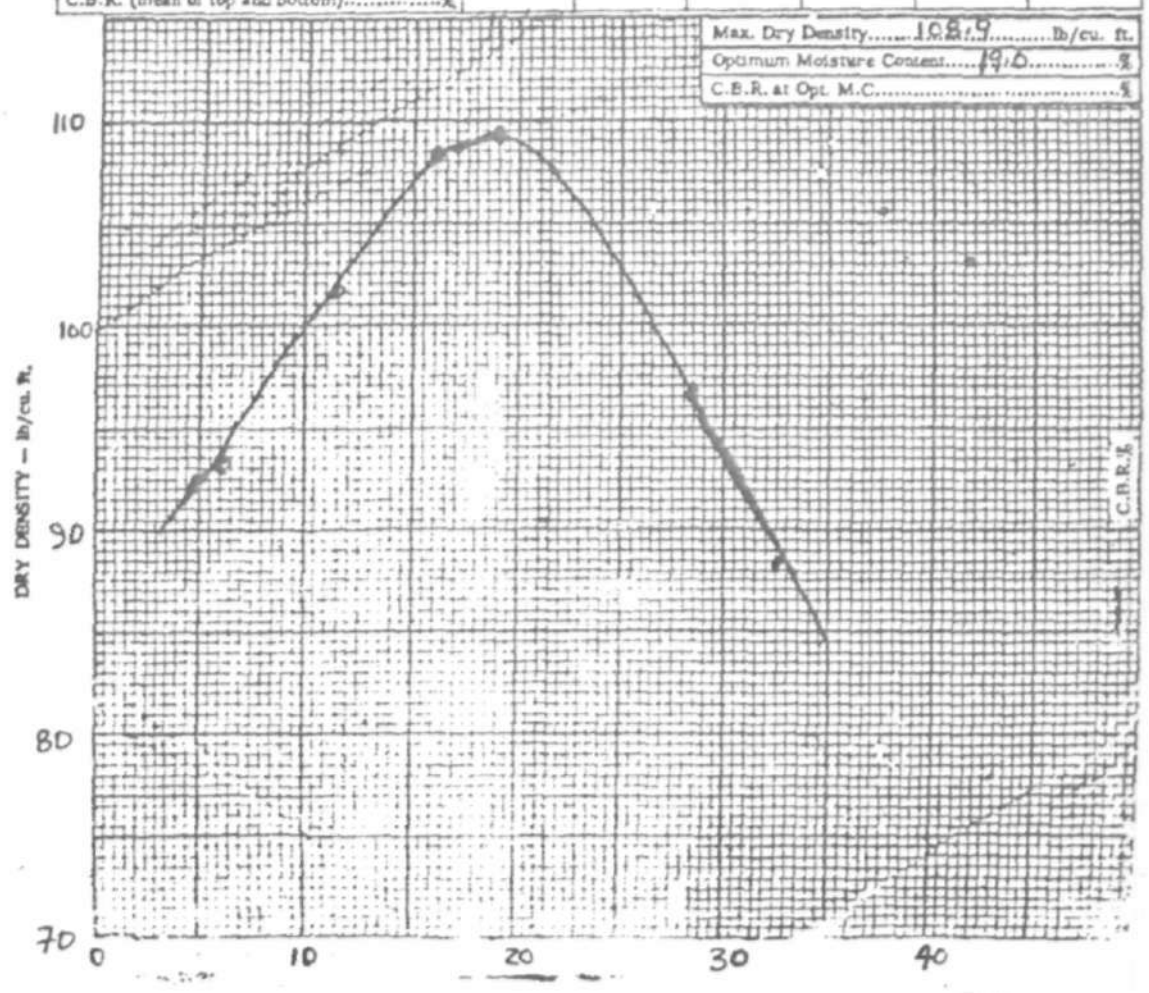
B.S.*/C.B.R.* Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	5560	5695	5960	6015	5918	5825	
Wt. of mould.....(W1).....g	4050	4050	4050	4050	4050	4050	
Wt. of wet soil.....(W2 - W1).....g	1510	1625	1910	1965	1865	1775	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	99.87	107.47	126.32	129.96	123.35	117.37	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	200	307	306	204	208	201	404	207	401	213	202	406
Wt. of wet soil and container.....g	643	673	637	576	594	662	594	677	575	544	712	612
Wt. of dry soil and container.....g	614	644	593	538	541	598	532	615	495	476	596	498
Wt. of container.....g	149	212	209	201	204	209	210	210	213	207	211	150
Wt. of dry soil (Ws).....g	465	432	384	337	337	389	322	322	282	269	379	348
Wt. of moisture (Ww).....g	29	24	44	38	53	64	62	62	80	73	122	113
Moisture content 100 Ww/Ws.....%	6.2	5.6	11.5	11.3	15.7	16.5	19.3	19.3	28.4	27.3	32.2	32.5
Average moisture content (m).....%	5.9		11.4		16.1		19.3		27.9		32.4	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft.	94.30		96.48		108.88		108.94		96.44		88.67	
C.B.R. (mean of top and bottom).....%												



FORM F ...2% Cement...

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL
USING STANDARD*/HEAVY* COMPACTION

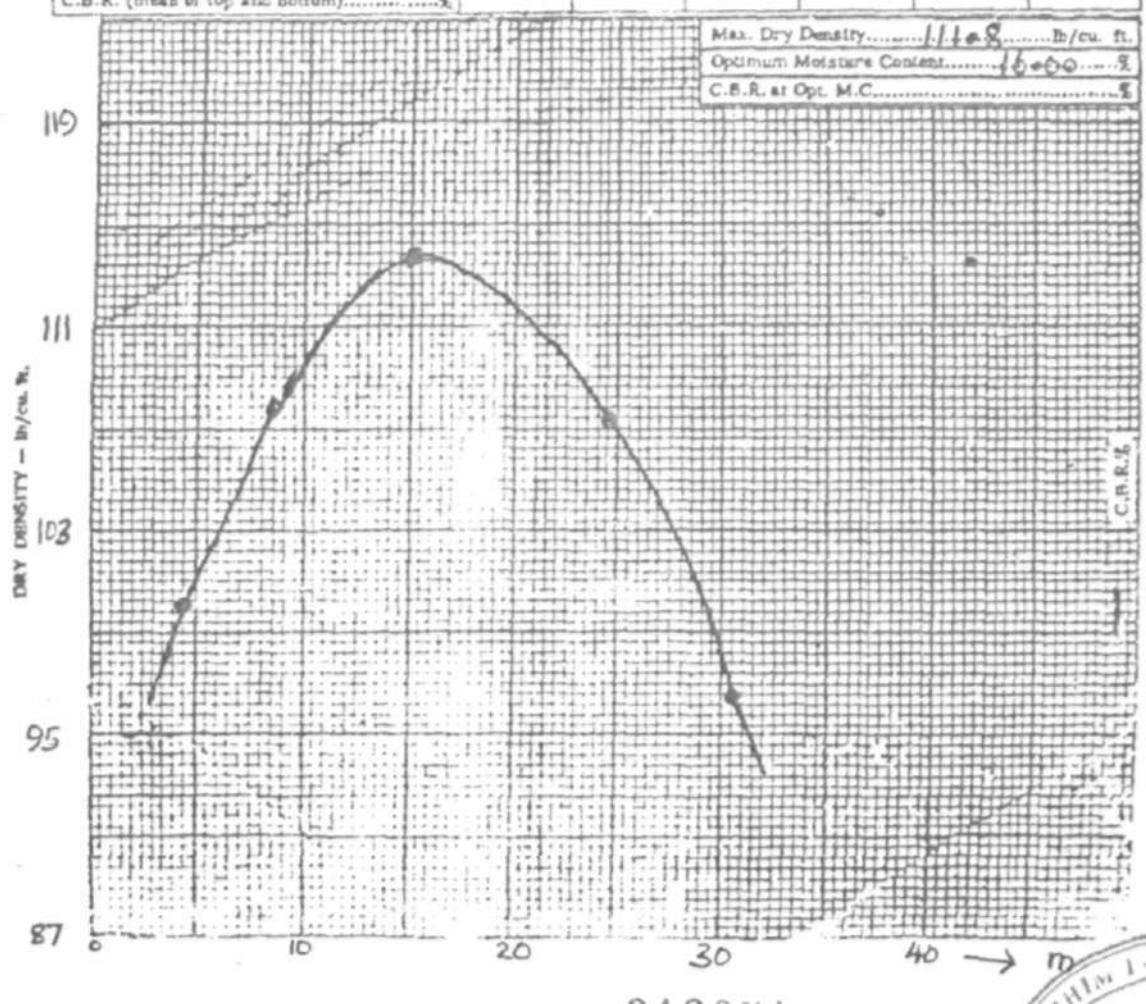
Job...M.S.C...PROJECT.....Sample No.....Operator...M.M. AWAISU
Site...ABUTH.....Shika...Depth.....1:98m.....Date.....
Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample...3000...g.....
B.S.*/~~C.B.R.*~~ Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	6005	6110	6395	6445	6320	6220	
Wt. of mould.....(W1).....g	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1).....g	1585	1690	1975	2025	1900	1800	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	104.83	111.77	130.62	133.93	125.66	119.05	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	125	10	66	0	58	22	60	2	24	74	71	32
Wt. of wet soil and container.....g	465	444	492	478	493	438	453	477	677	678	716	670
Wt. of dry soil and container.....g	445	430	462	442	446	389	383	397	545	536	558	515
Wt. of container.....g	9.7	9.4	5.5	8.6	8.6	8.5	8.8	8.5	9.4	8.8	8.8	8.9
Wt. of dry soil (Ws).....g	358	336	407	356	359	304	295	315	451	450	470	426
Wt. of moisture (Ww).....g	2.0	1.4	3.0	3.6	4.8	4.9	7.0	8.0	13.2	14.0	15.8	15.5
Moisture content 100 Ww/Ws.....%	5.59	4.17	7.37	10.11	13.37	16.12	23.73	25.4	29.27	31.11	33.62	36.4
Average moisture content (m).....%	4.88		8.74		14.75		24.57		30.19		35.01	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft.	99.95		107.79		113.83		107.57		96.52		88.18	
C.B.R. (mean of top and bottom).....%												



313051

FORM F 4% Cement

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job... M.Sc. PROJECT.....Sample No.....Operator... M.M. ANYANSU

Site... A.B.U.T.H. ... Sitka...Depth.....1.98m.....Date.....

Amount retained on 3/4" B.S. Sieve .....g.....Total weight of sample...3.000....g.....

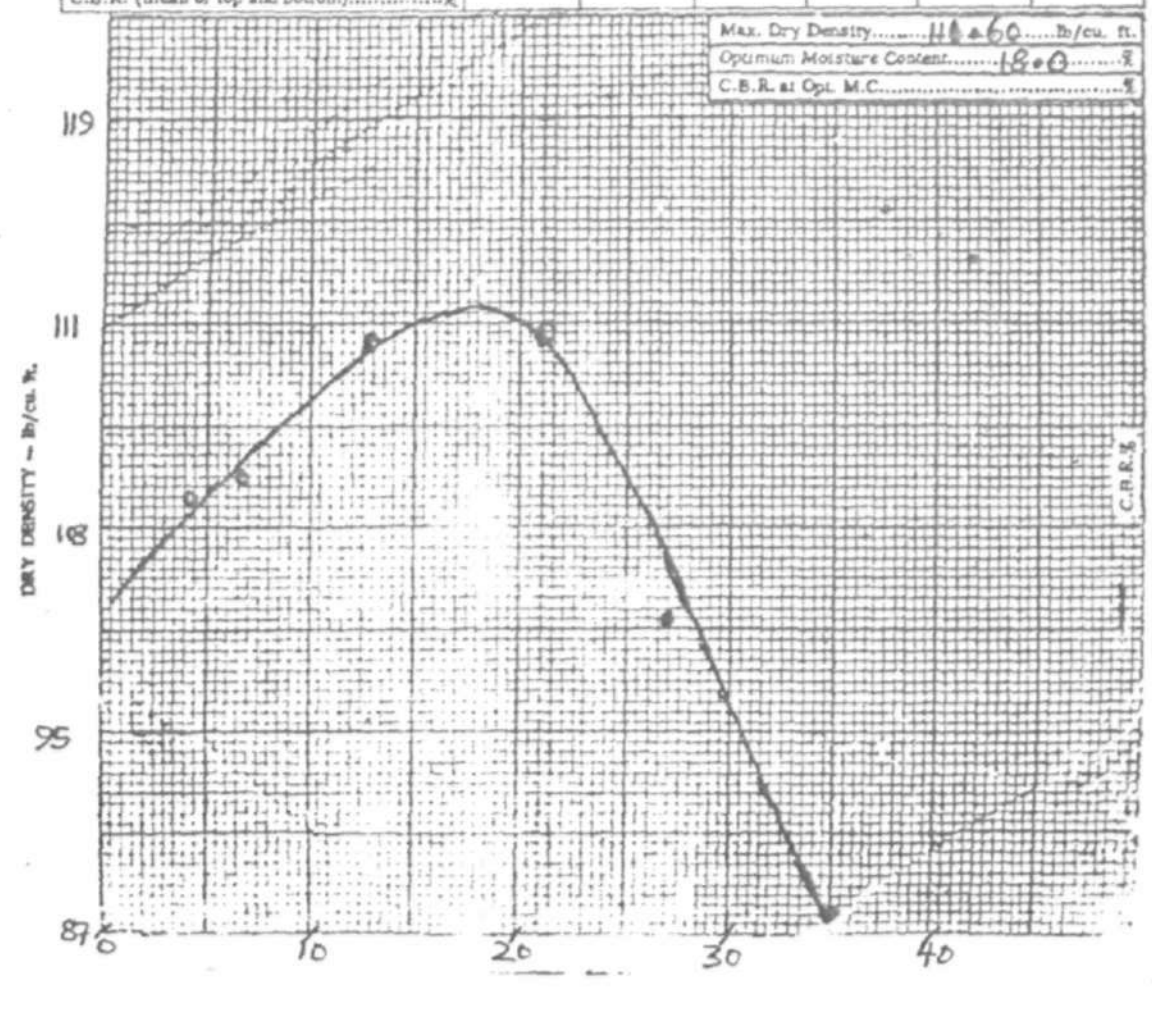
B.S.*/C.B.R.* Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g.	6070	6110	6310	6440	6315	6210	
Wt. of mould.....(W1).....g.	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1).....g.	1650	1690	1890	2020	1895	1790	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	109.13	111.77	125.00	133.61	125.35	118.39	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	41	34	60	55	17	15	8	11	18	56	44	46
Wt. of wet soil and container.....g.	36.6	30.4	39.7	41.3	45.5	46.5	55.0	54.0	64.2	78.6	78.2	69.5
Wt. of dry soil and container.....g.	35.5	29.6	37.8	39.4	40.4	42.1	52.0	48.6	59.5	66.5	62.9	57.4
Wt. of container.....g.	8.8	9.3	9.0	8.9	8.8	9.7	21.3	21.3	21.1	21.3	20.8	20.8
Wt. of dry soil (Wd).....g.	26.7	20.3	28.8	30.5	31.6	32.4	30.7	27.3	38.4	45.2	42.1	36.6
Wt. of moisture (Ww).....g.	1.1	0.8	1.9	1.9	5.1	3.4	7.0	5.4	9.7	12.1	15.3	12.1
Moisture content 100 Ww/Wd.....%	4.12	3.94	6.59	6.23	16.14	10.49	21.80	19.75	25.26	26.6	36.3	33.1
Average moisture content (m).....%	4.03		6.41		13.32		20.79		25.97		34.70	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft	104.90		105.04		110.31		110.60		99.49		87.89	
C.B.R. (mean of top and bottom).....%												



FORM F ....6% cement....

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL
USING STANDARD*/HEAVY* COMPACTION

Job....MISC PROJECT.... Sample No.....Operator....AINAIGU M.M.

Site....A.P.U.T.I. SHKA....Depth....1:9E....Date....25/1/89....

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample....3000....g.....

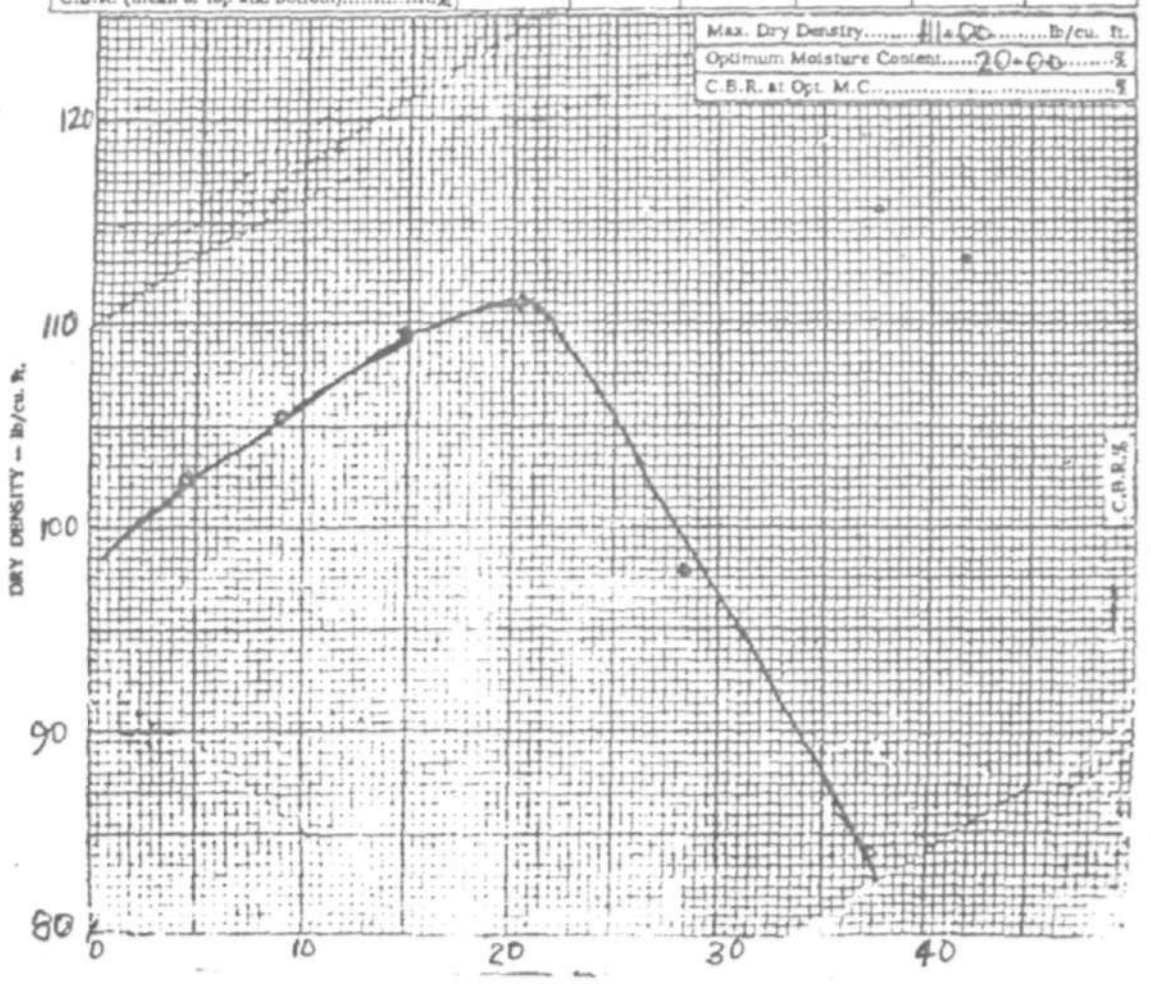
B.S.*/C.B.R.* Mould:.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	6105	6140	6330	6450	6290	6160	
Wt. of mould.....(W1).....g	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1).....g	1685	1720	1910	2030	1870	1740	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	111.44	113.76	126.32	134.26	123.68	115.08	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.....	68	33	14	3	600	A1	15	48	36	50	9	31
Wt. of wet soil and container.....g	68.3	65.3	62.3	62.5	67.8	66.3	72.4	72.8	74.0	72.7	88.2	85.4
Wt. of dry soil and container.....g	66.7	63.2	59.0	59	60.2	61.9	63.7	63.9	62.4	61.2	70.2	67.8
Wt. of container.....g	20.6	20.5	21.3	20.7	20.7	20.9	20.9	21.1	20.8	21.0	21.0	20.4
Wt. of dry soil (Ws).....g	46.1	42.7	37.7	38.3	39.5	41.	42.8	42.8	41.5	40.2	49.2	47.4
Wt. of moisture (Ww).....g	1.6	2.1	3.5	3.5	7.6	4.4	8.7	8.9	11.6	11.5	18	17.6
Moisture content (%) Ww/Ws.....%	3.47	4.92	8.75	9.14	19.24	10.73	20.33	20.79	27.95	28.61	36.59	37.13
Average moisture content (m).....%	4.20		8.95		14.99		20.56		28.28		36.86	
Dry density $\gamma_d = 100\gamma/100+m$.....lb/cu. ft.	102.95		104.41		109.85		111.36		96.41		84.09	
C.B.R. (mean of top and bottom).....%												



FORM F 8% Cement

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job.....Sample No...../.....Operator.....AWAISU M.M

Site.....Dep'n.....Date.....25/1/89

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample.....g.....

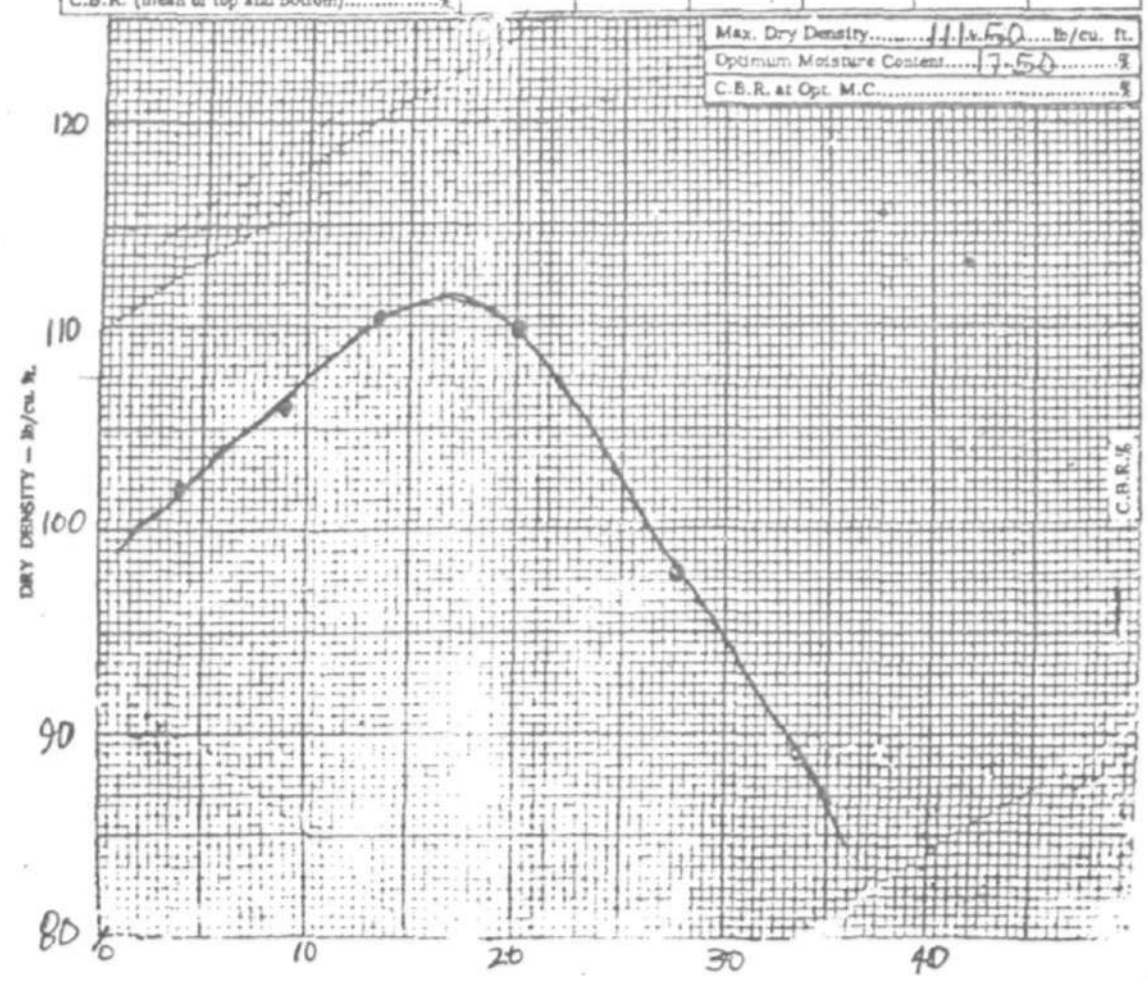
B.S.*/C.B.R.* Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	6060	6105	6320	6420	6310	6245	
Wt. of mould.....(W1).....g	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1).....g	1640	1685	1900	2000	1890	1825	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$ .....lb/cu. ft.	108.47	111.44	125.66	132.28	125.0	120.70	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.	13	11	5	7	12	68	6	9	13	32	21	47
Wt. of wet soil and container.....g	69.8	64.1	65.1	78.3	66.3	60.1	59.8	64.8	71.9	64.0	81.0	78.2
Wt. of dry soil and container.....g	68.0	62.2	61.4	73.8	60.4	55.8	53.1	57.6	60.3	54.7	65.6	59.5
Wt. of container.....g	21.1	21.0	21.0	20.6	20.8	20.8	20.8	20.7	20.8	20.8	21.5	20.9
Wt. of dry soil (Ws).....g	46.9	41.2	40.4	53.2	39.6	35.0	32.3	36.9	39.5	33.9	44.1	38.6
Wt. of moisture (Wa).....g	1.8	1.9	3.7	4.5	5.9	4.3	6.7	7.2	11.6	9.3	15.4	13.7
Moisture content 100 Wa/Ws.....%	3.84	4.61	9.16	8.46	14.95	12.29	20.74	19.51	28.35	27.43	34.92	35.49
Average moisture content (m).....%	4.23		8.81		13.60		20.13		28.40		35.21	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu.ft	103.07		104.42		110.62		110.12		97.35		89.27	
C.B.R. (mean of top and bottom).....%												



FORM F ....10% Cement....

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOIL USING STANDARD*/HEAVY* COMPACTION

Job..M.Sc. PROJECT.....Sample No.....Operator..ANAISU M.M.

Site..A.B.U.T.H. SHIKA..Depth.....1:98m.....Date..25/1/89 5.00pm

Amount retained on 3/4" B.S. Sieve.....g.....Total weight of sample..3000.....g.....

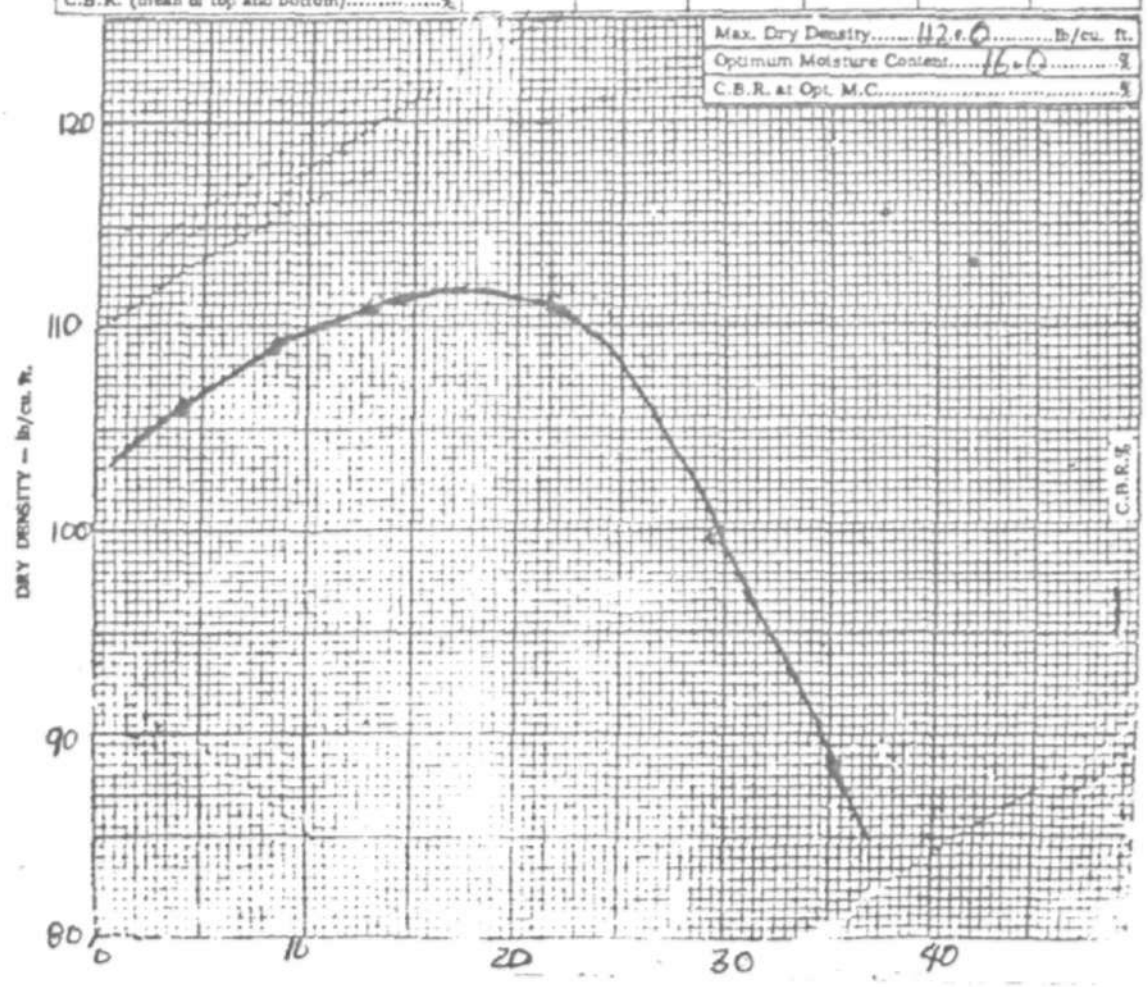
B.S.*/C.B.R.* Mould.....*Delete the inappropriate word

Wt. of mould and wet soil.....(W2).....g	6150	6205	6330	6490	6370	6230	
Wt. of mould.....(W1).....g	4420	4420	4420	4420	4420	4420	
Wt. of wet soil.....(W2 - W1).....g	1730	1785	1910	2070	1950	1810	
Bulk density $\gamma = \frac{W_2 - W_1}{X}$.....lb/cu. ft.	114.42	118.06	126.32	136.90	128.97	119.71	

For B.S. Mould X = 15.12 For C.B.R. Mould X = 37.11

MOISTURE CONTENT DETERMINATIONS

Container No.	193	46	74	164	35	163	60	161	66	2	42	179
Wt. of wet soil and container.....g	40.4	45.2	51.7	60.0	51.9	55.4	41.1	47.8	68.5	64.7	60.7	79.4
Wt. of dry soil and container.....g	39.4	43.5	48.2	56.3	47.5	49.0	39.8	40.6	56.0	52.5	46.5	60.5
Wt. of container.....g	8.7	9.1	9.1	8.2	8.6	8.3	8.5	8.7	5.5	9.0	5.2	8.4
Wt. of dry soil (Ws).....g	30.4	34.4	39.1	48.1	38.9	40.7	30.9	31.9	49.5	43.5	41.3	52.1
Wt. of moisture (Wm).....g	1.0	1.7	3.5	3.70	4.4	6.4	6.3	7.2	14.5	12.2	14.2	8.9
Moisture content 100 Wm/Ws.....%	3.20	4.94	8.95	7.69	11.31	15.72	20.39	22.57	29.28	28.05	34.38	36.38
Average moisture content (m).....%	4.10		8.32		13.52		21.48		28.67		35.31	
Dry density $\gamma d = 100\gamma/100+m$.....lb/cu. ft.	106.91		108.99		111.28		112.69		100.23		88.47	
C.B.R. (mean of top and bottom).....%												



APPENDIX D

CBR TEST RESULTS FOR BOTH SOAKED AND UNSOAKED CASES FOR SOIL - STABILIZERS.

NOTE:

CBR MACHINE'S FACTOR = 0.01286KN/DIV

= 2.891lb/DIV

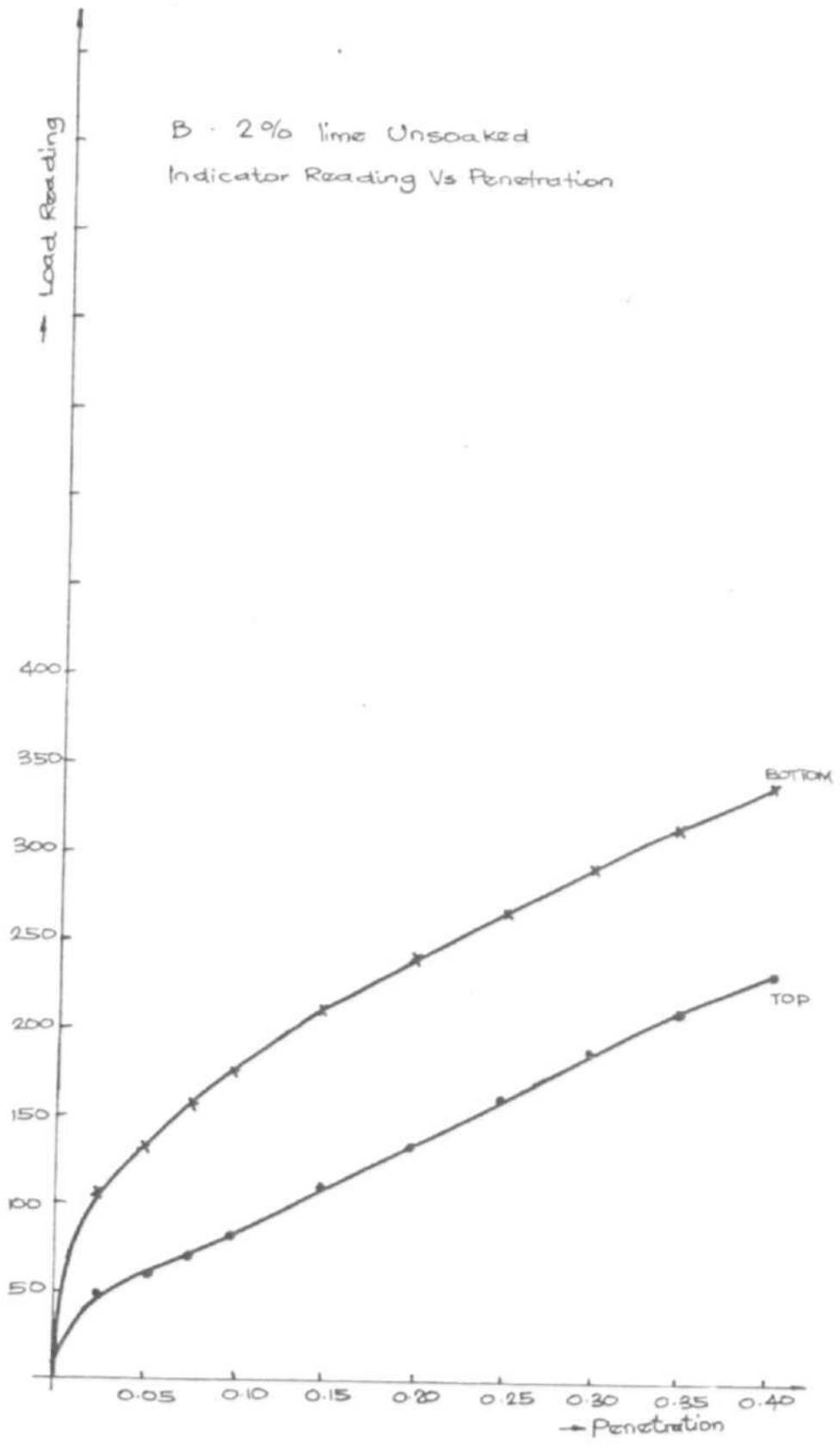
HENCE,

LOAD (lb) = LOAD INDICATOR READING x 2.891.

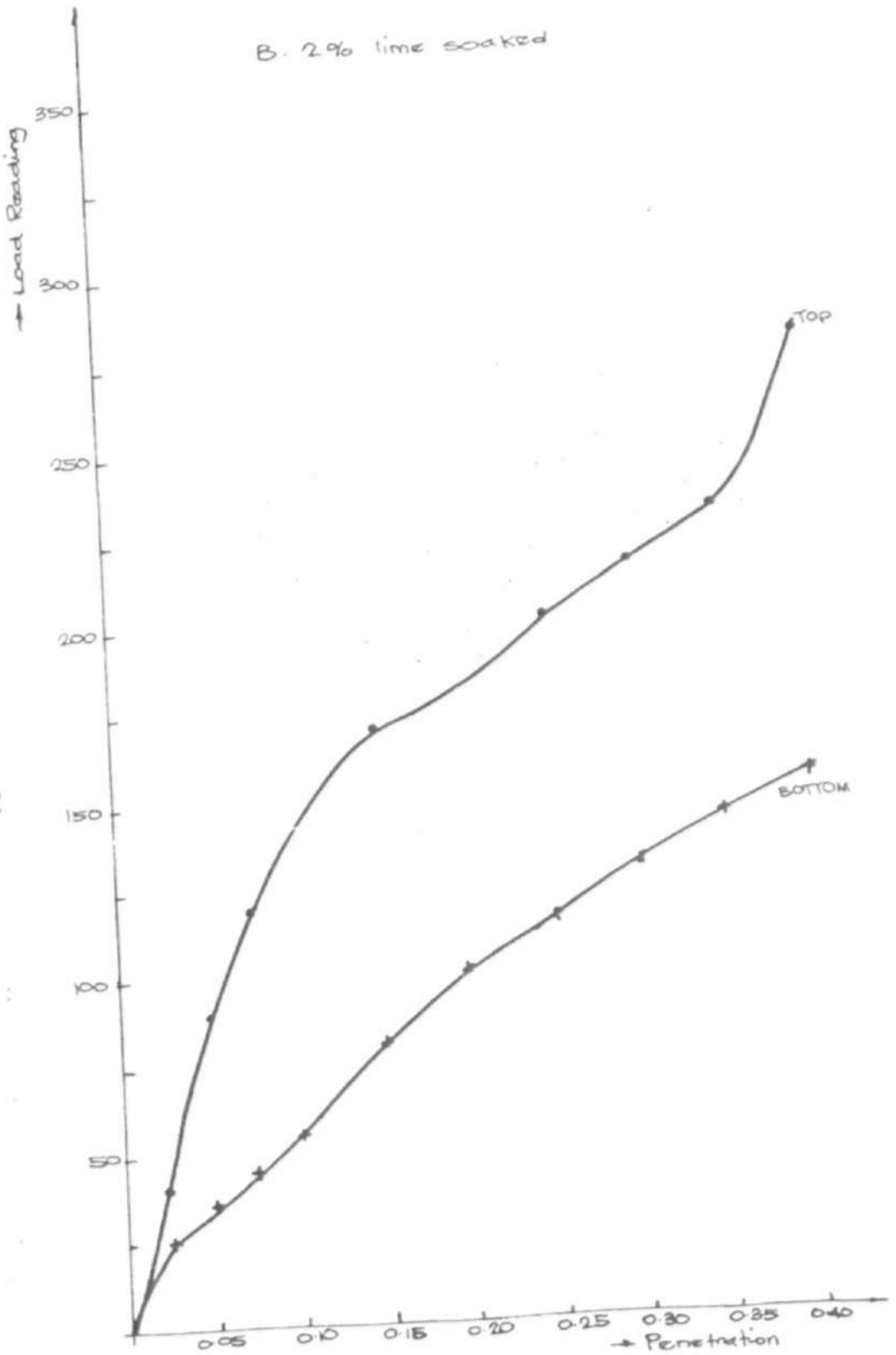
Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	48	105	40	25
0.050	60	130	90	35
0.075	70	155	120	45
0.100	81	175	140	55
0.150	109	209	170	80
0.200	133	238	180	100
0.250	160	265	200	115
0.300	187	290	215	130
0.350	210	312	230	143
0.400	230	335	280	153
0.450	253	338	300	160
0.500	270	380	350	171
CBR %	8,55	16.87	13.49	6.42
Average	12.71		9.96	

CBR RESULT FOR B 2% Lime ..... Stabilizer

B · 2% lime Unsoaked
Indicator Reading Vs Penetration

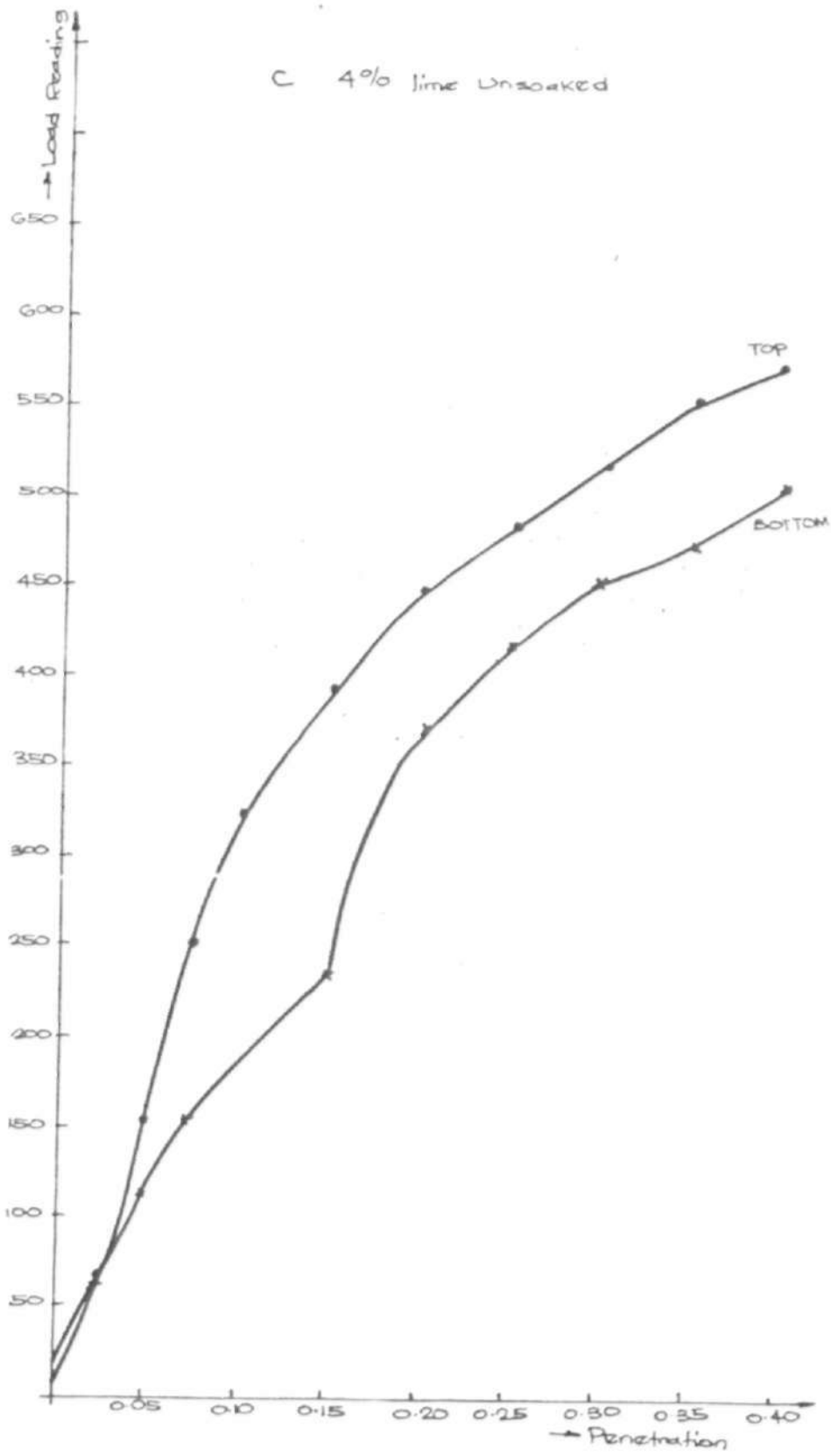


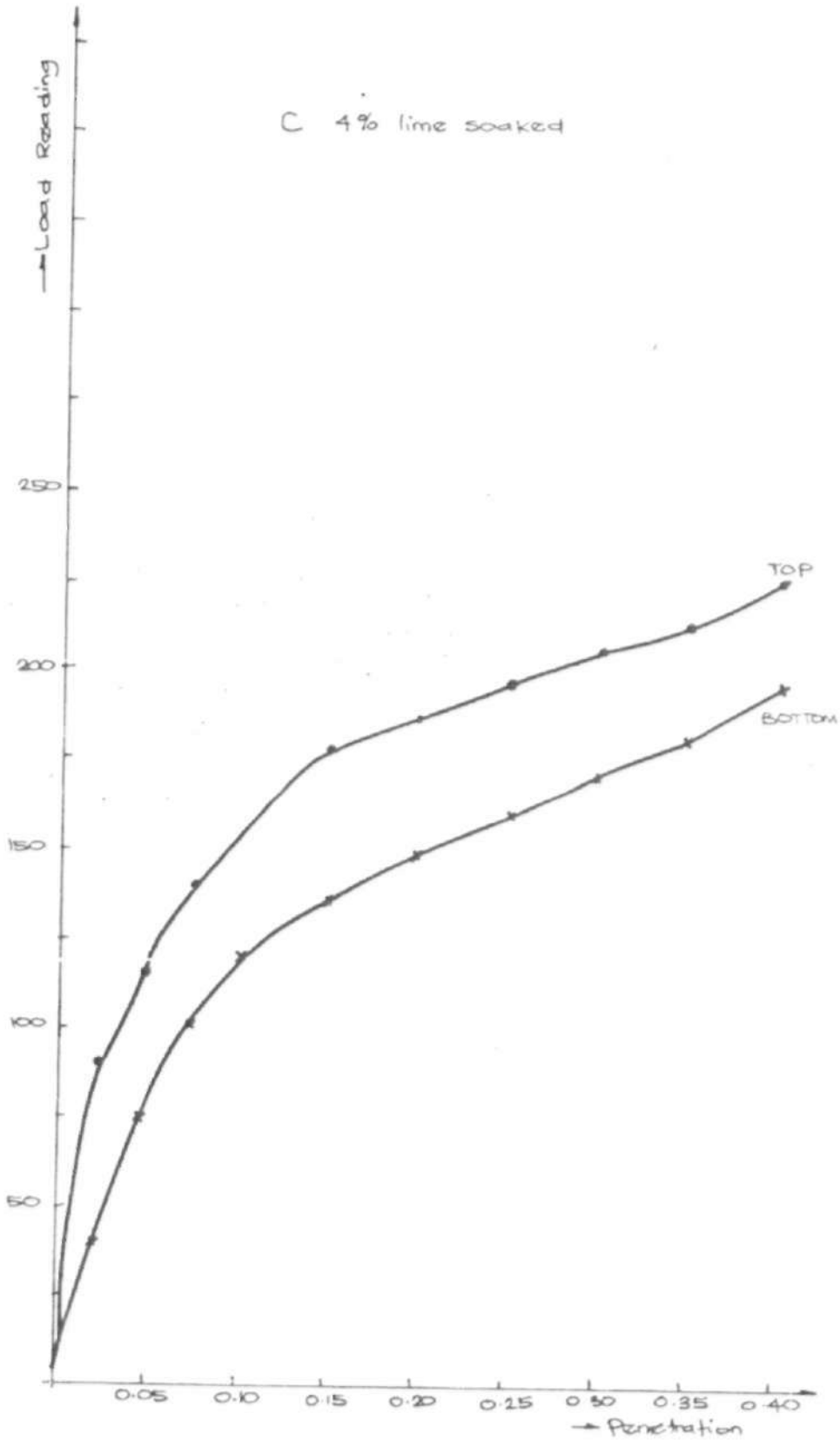
B. 2% lime soaked



Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	63	60	90	40
0.050	150	110	115	75
0.075	250	150	140	100
0.100	320	180	153	120
0.150	390	230	177	135
0.200	445	370	185	148
0.250	480	415	195	159
0.300	515	450	205	170
0.350	550	470	210	180
0.400	570	505	225	195
0.450	595	540	240	205
0.500	625	605	270	230
CBR %	30.84	23.77	14.75	11.56
Average	27.31		13.16	

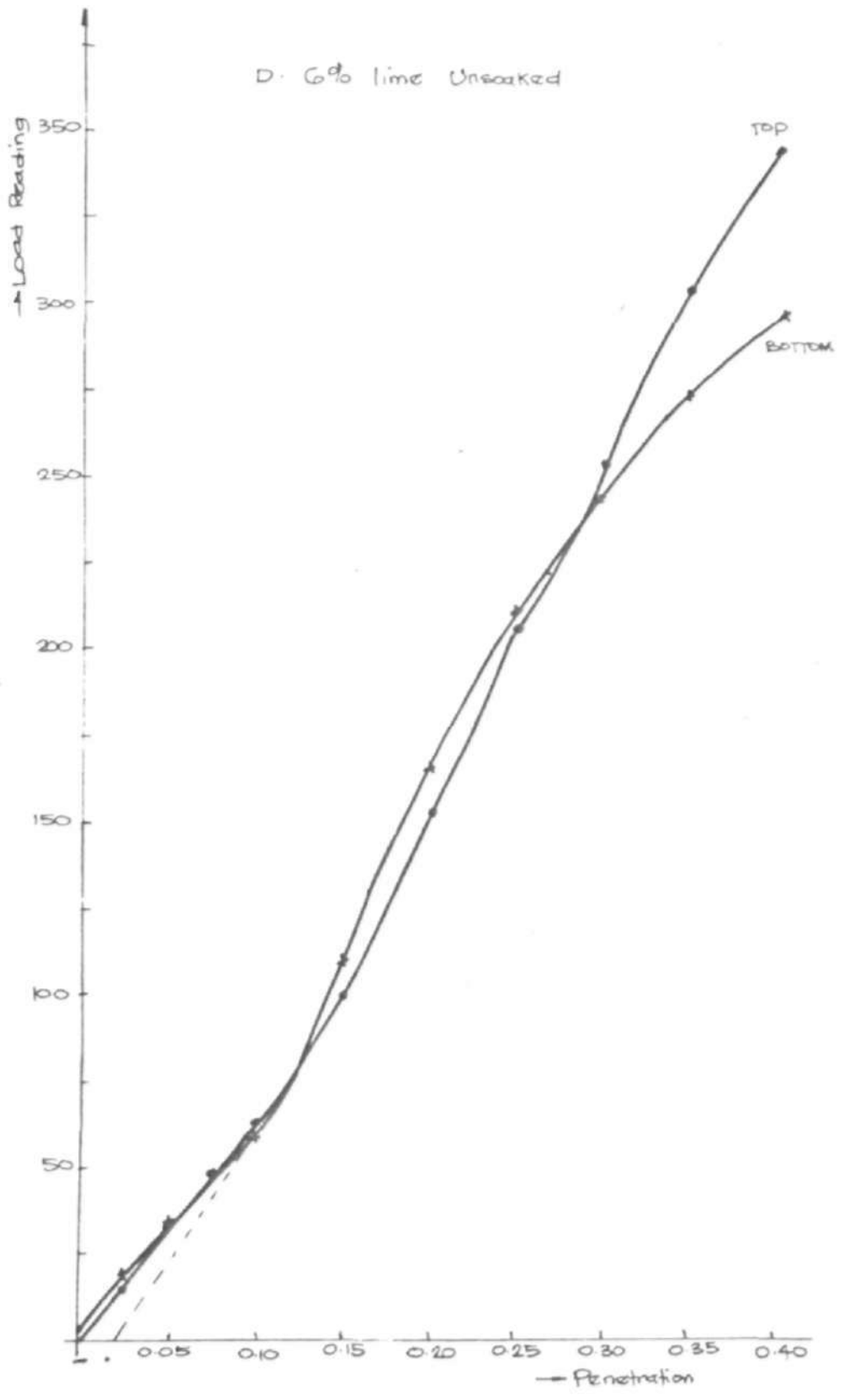
CBR RESULT FOR .C.4%..Lime..... Stabilizer


C 4% lime Unsoaked
Load Reading
650
600
550
500
450
400
350
300
250
200
150
100
50
TOP
BOTTOM
0·05
0·10
0·15
0·20
0·25
0·30
0·35
0·40
Penetration

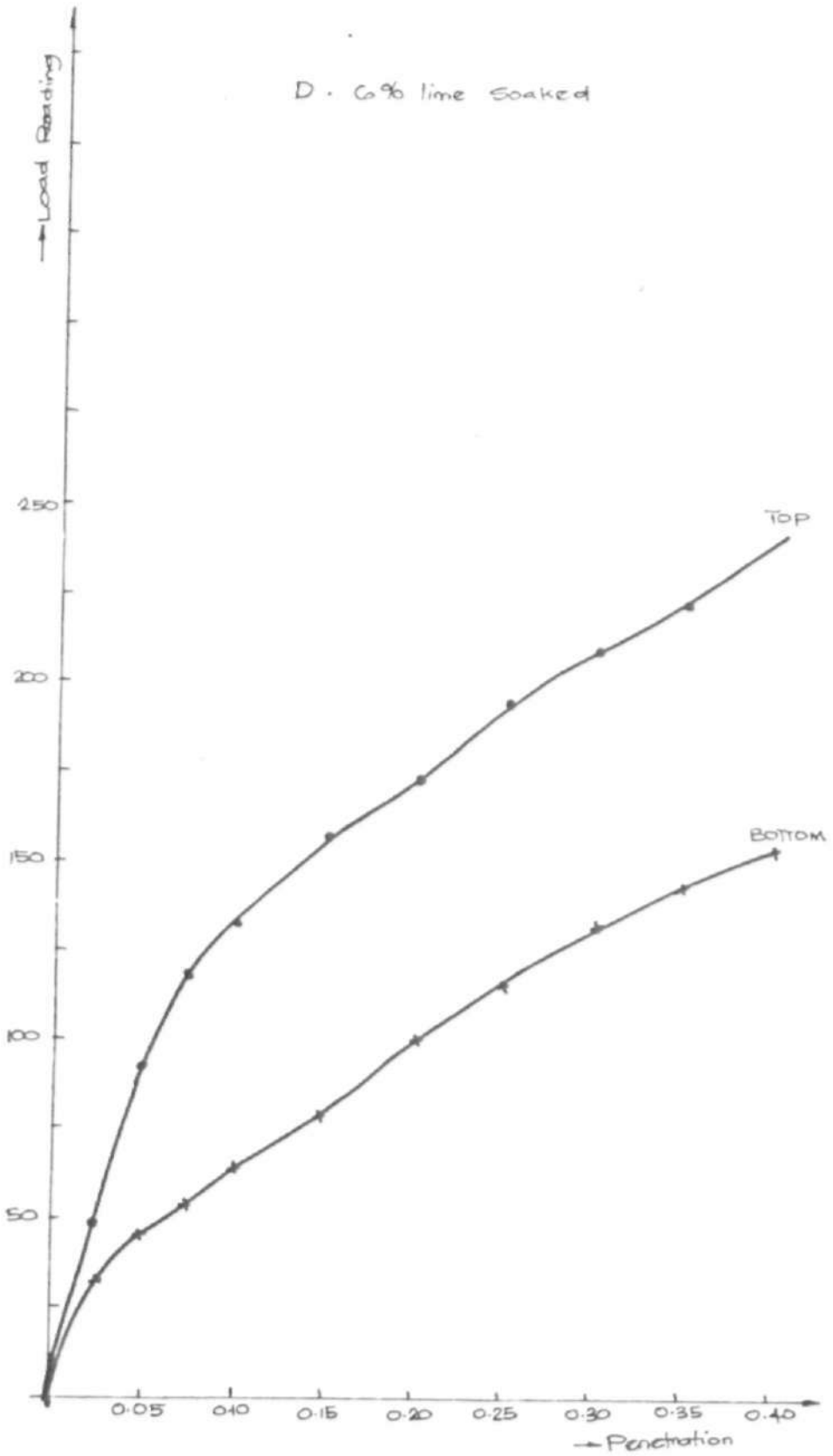

C 4% lime soaked
Load Reading
250
200
150
100
50
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	15	20	48	32
0.050	34	35	92	46
0.075	48	48	118	53
0.100	62	58	132	65
0.150	100	110	156	78
0.200	152	165	172	100
0.250	205	210	192	115
0.300	252	242	208	132
0.350	302	270	221	142
0.400	340	292	240	153
0.450	383	315	251	171
0.500	413	340	261	183
CBR %	9.77	10.60	12.72	6.46
Average	10.19		9.59	

CBR RESULT FOR D 6% Lime..... Stabilizer

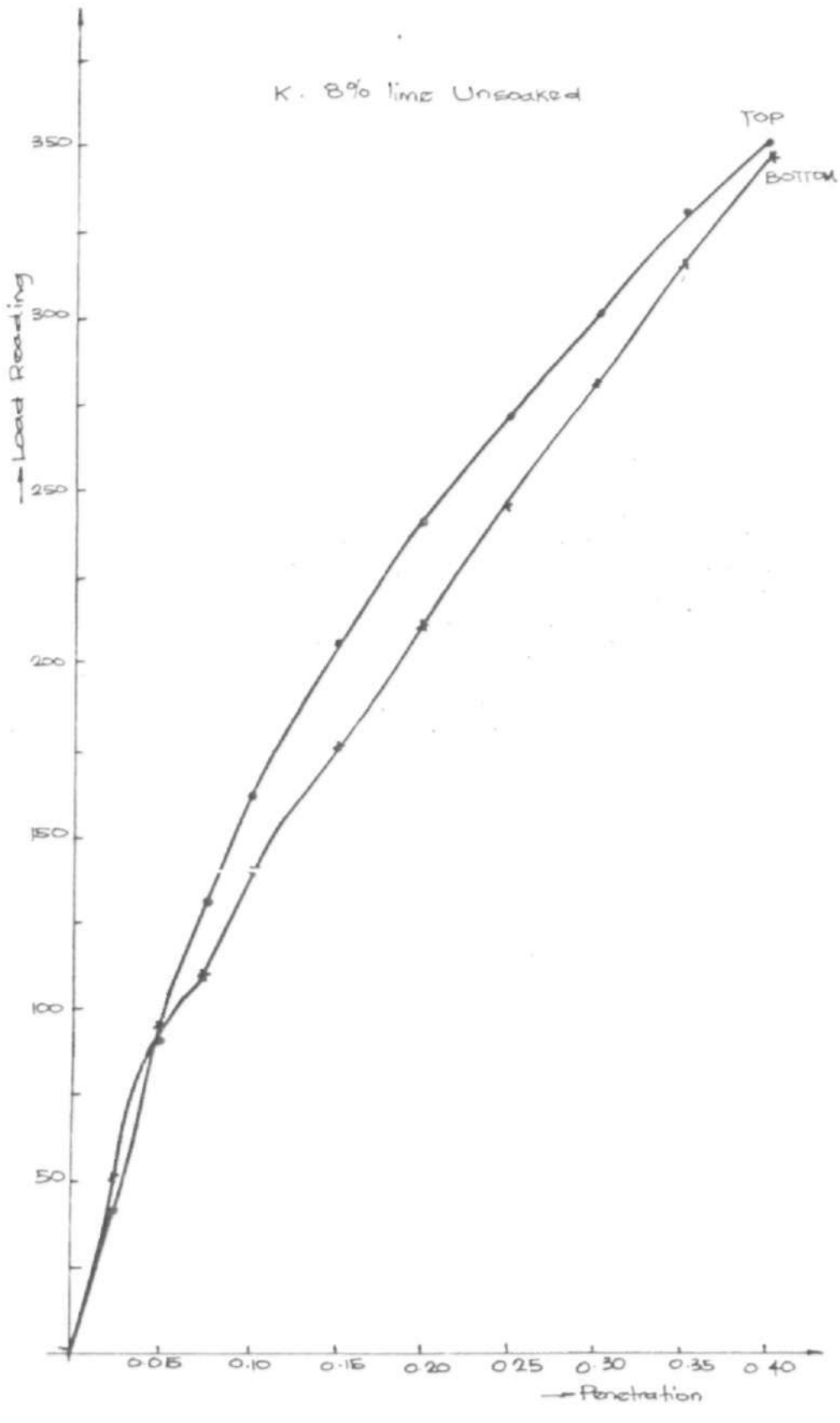

D. 6% lime Unsoaked
Load Reading
350
300
250
200
150
100
50
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

D. 6% lime Soaked

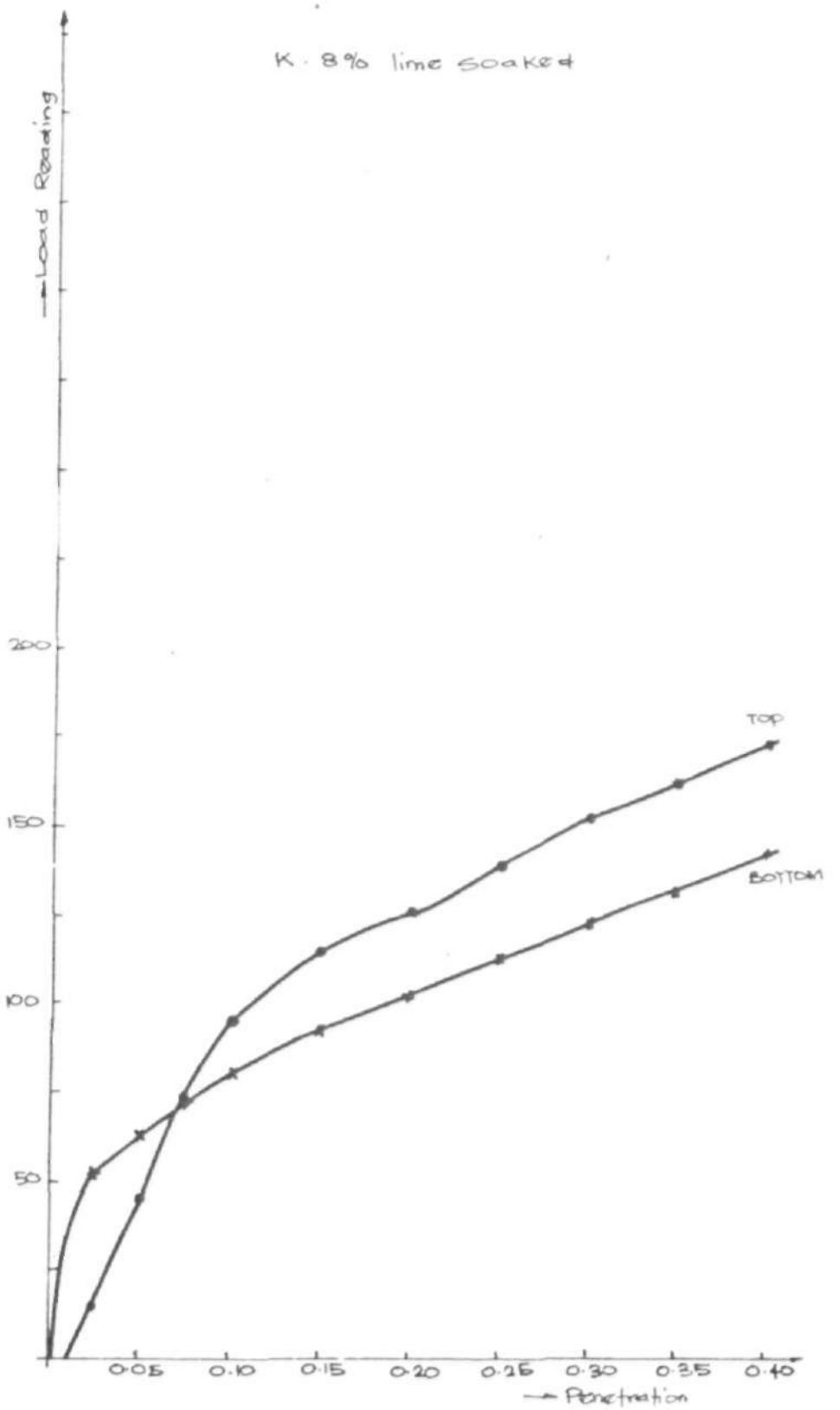


Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.8000	0	0	0	0
0.025	40	50	15	53
0.050	90	95	45	63
0.075	130	110	73	73
0.100	160	140	95	80
0.150	205	175	115	92
0.200	240	210	125	102
0.250	270	245	138	112
0.300	300	280	152	122
0.350	330	315	161	131
0.400	350	345	173	142
0.450	378	375	184	153
0.500	403	406	200	165
CBR %	15.42	13.49	9.16	7.71
Average	14.46		8.44	

CBR RESULT FOR K 8% Lime ..... Stabilizer

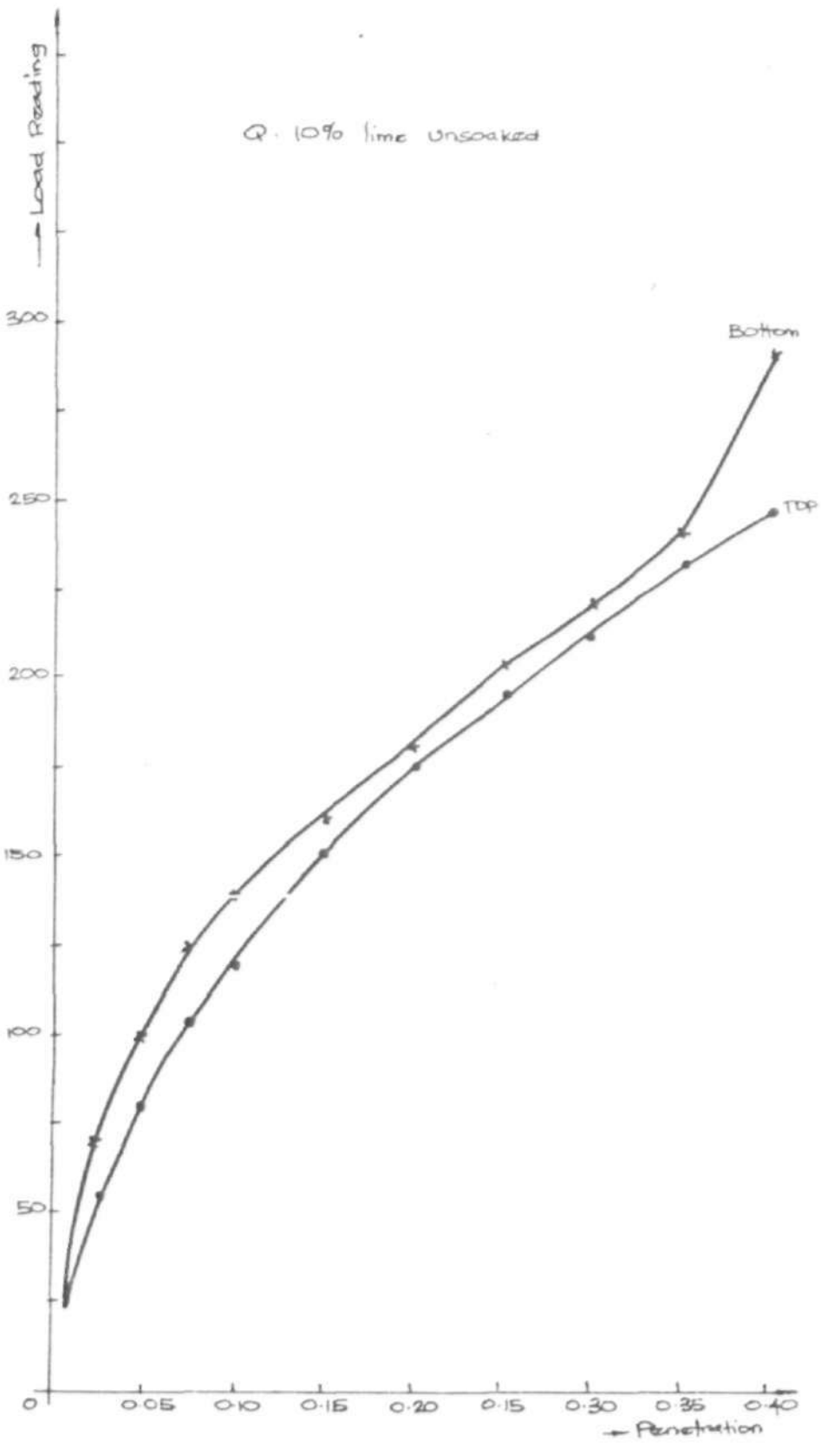

K. 8% lime Unsoaked
TOP
BOTTOM
Load Reading
350
300
250
200
150
100
50
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

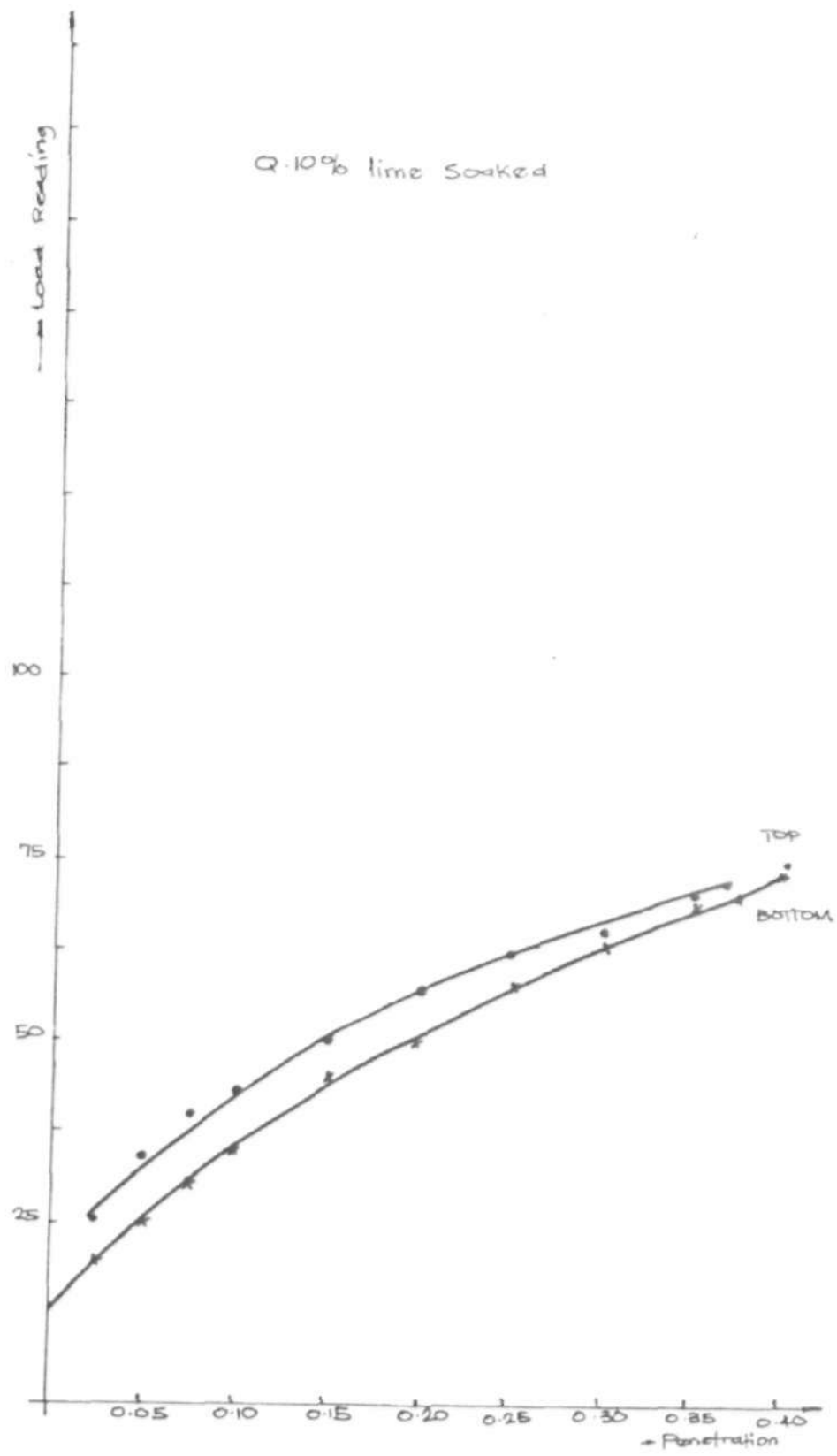
K · 8% lime soaked



Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	55	70	25	20
0.050	80	100	34	25
0.075	103	125	40	30
0.100	120	140	43	35
0.150	150	160	50	45
0.200	175	180	57	50
0.250	195	203	62	57
0.300	210	220	65	63
0.350	230	240	70	69
0.400	245	290	74	73
0.450	260	310	80	76
0.500	290	350	83	80
CBR %	11.56	13.49	4.14	3.37
Average	12.53		3.76	

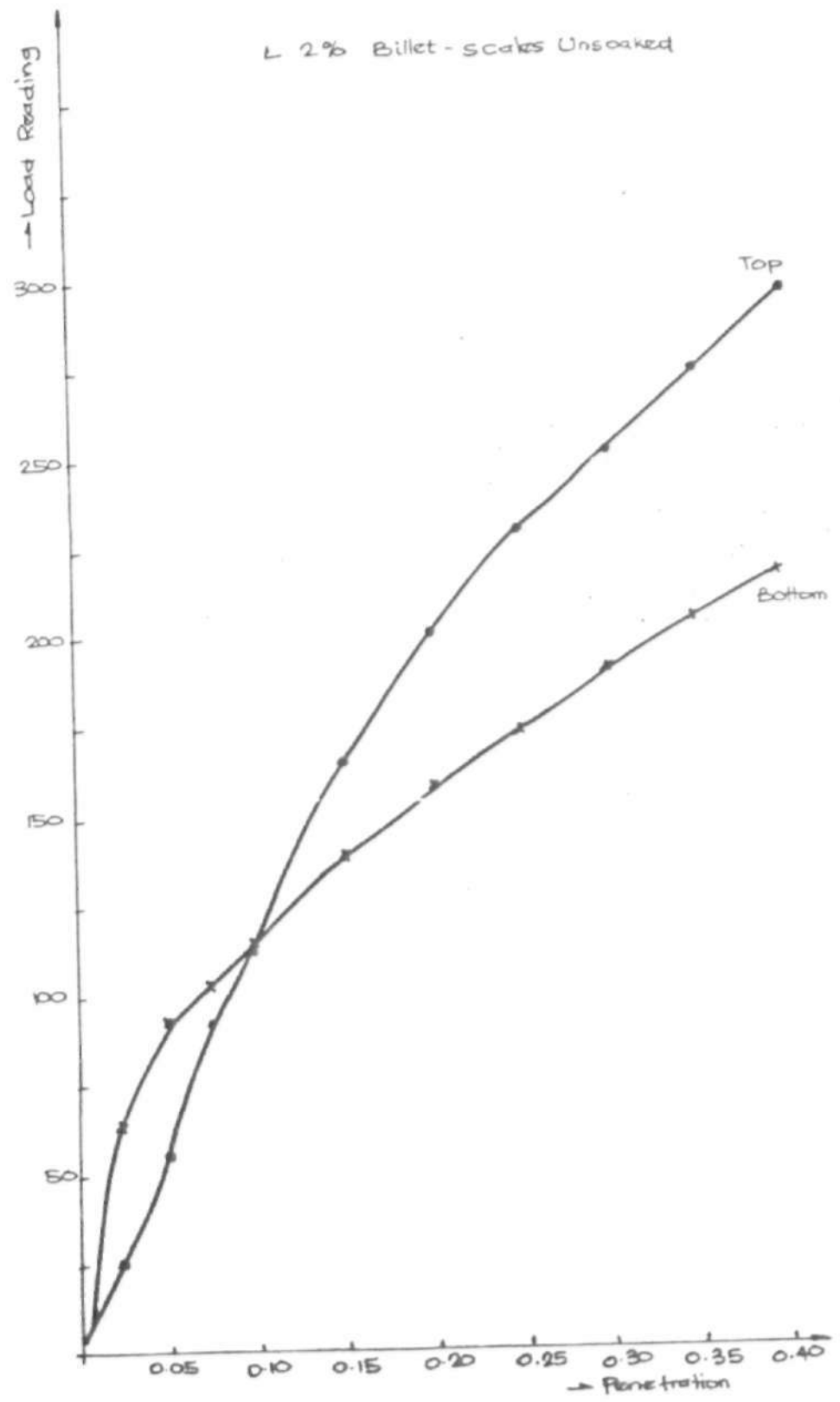
CBR RESULT FOR Q 10% Lime ..... Stabilizer


Q. 10% lime unsoaked
Load Reading
300
250
200
150
100
50
0
Bottom
TOP
0·05
0·10
0·15
0·20
0·15
0·30
0·35
0·40
Penetration


Q·10% lime Soaked
Load Reading
100
75
50
25
TOP
BOTTOM
0·05
0·10
0·15
0·20
0·25
0·30
0·35
0·40
Penetration

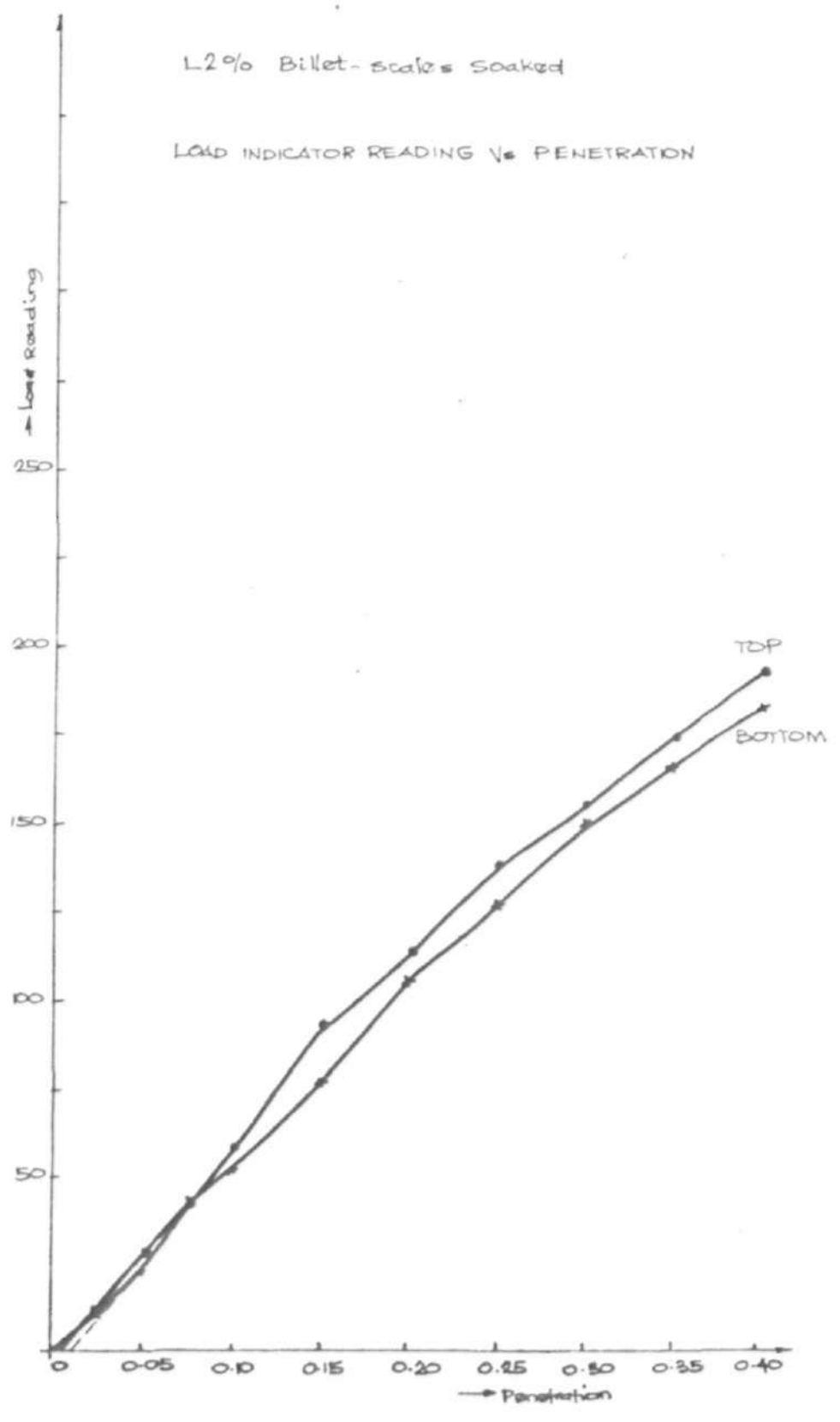
Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	25	64	12	12
0.050	55	93	24	28
0.075	92	103	42	42
0.100	112	115	58	51
0.150	164	140	92	83
0.200	200	157	112	105
0.250	230	173	138	126
0.300	250	190	155	150
0.350	273	204	173	165
0.400	294	215	192	182
0.450	310	230	210	205
0.500	320	250	230	215
CBR %	12.85	11.08	7.20	6.75
Average	(11.97)		(6.94)	

CBR RESULT FOR 2% Billet-Scale Stabilizer


L 2% Billet - Scales Unsoaked
Load Reading
300
250
200
150
100
50
Top
Bottom
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

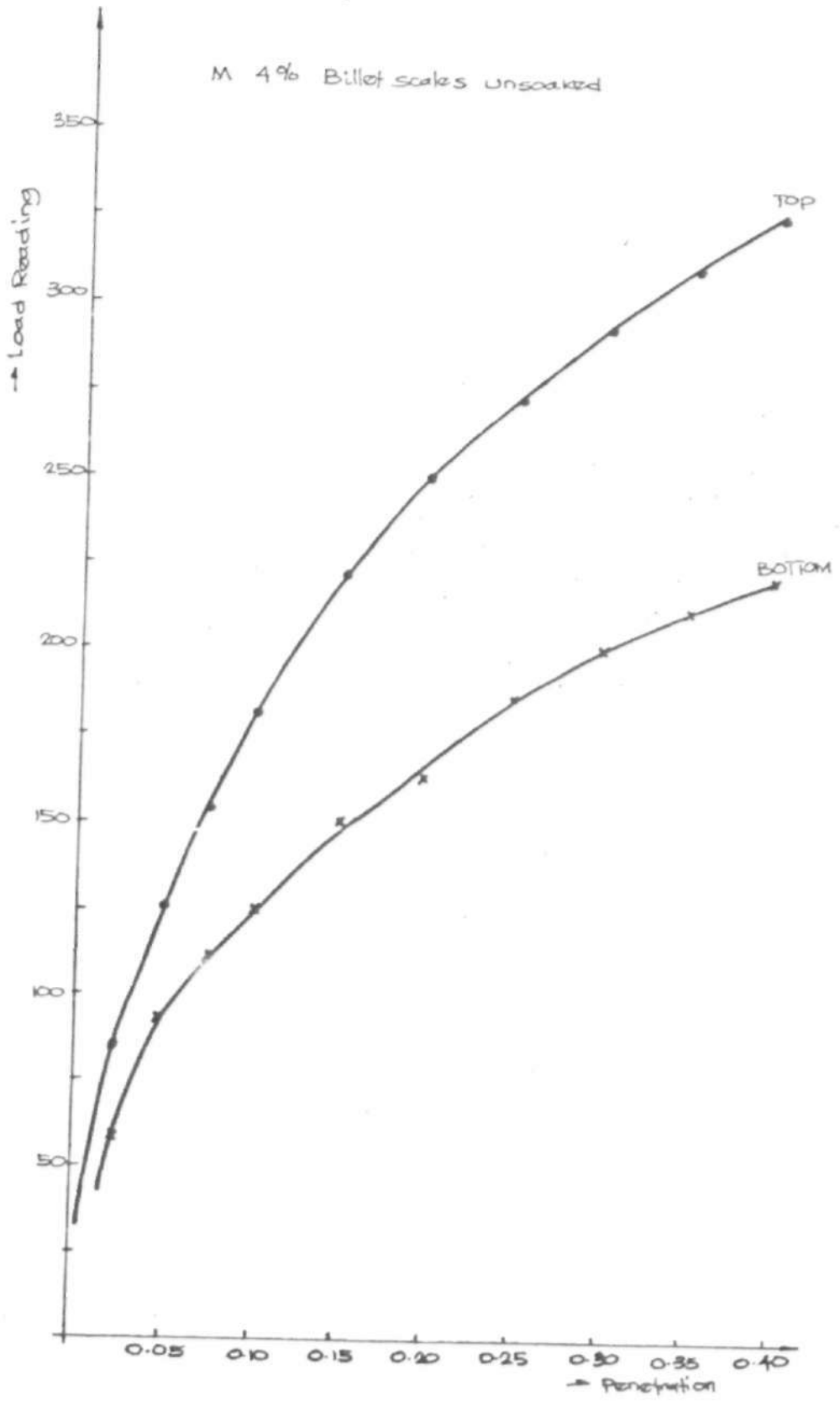
L2% Billet-scales Soaked

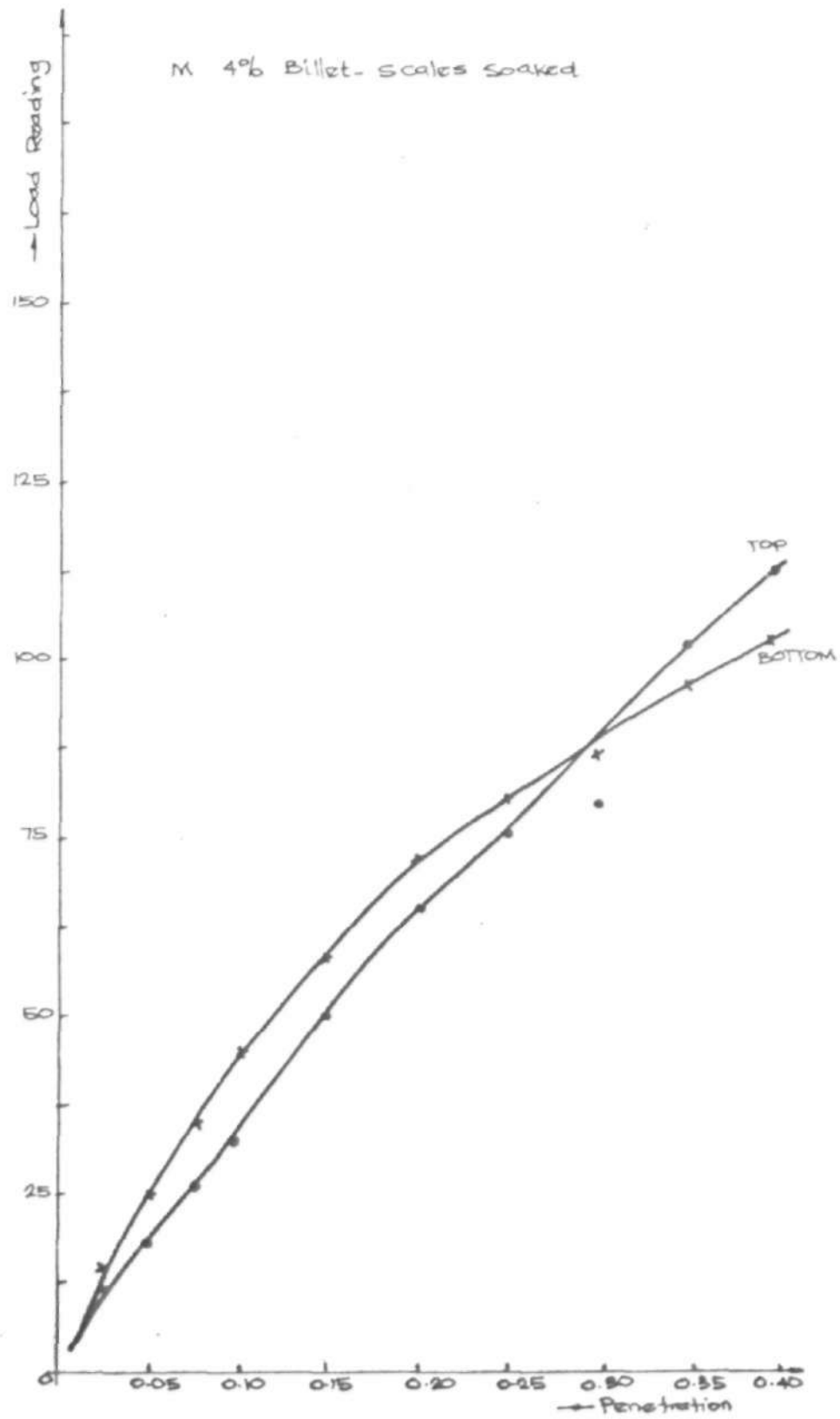
LOAD INDICATOR READING Vs PENETRATION



Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	84	58	12	15
0.050	124	92	18	25
0.075	153	110	26	35
0.100	180	125	32	45
0.150	221	152	50	58
0.200	249	163	65	72
0.250	273	185	75	80
0.300	292	200	92	86
0.350	310	210	102	96
0.400	325	221	112	102
0.450	342	253	121	110
0.500	358	265	130	117
CBR %	17.35	12.05	4.18	4.63
Average	14.70		4.41	

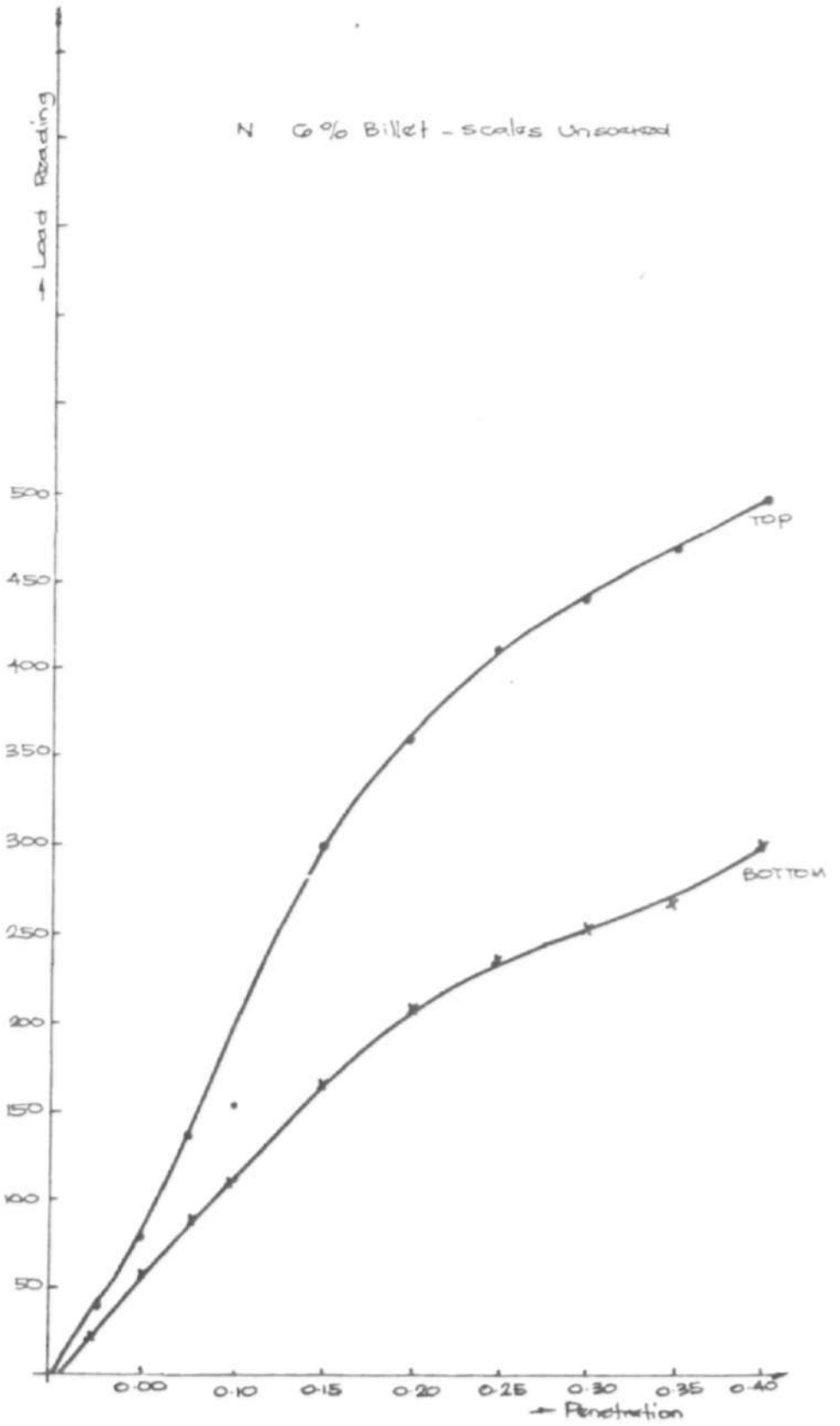
CBR RESULT FOR ..... 4% Billet-Scales Stabilizer

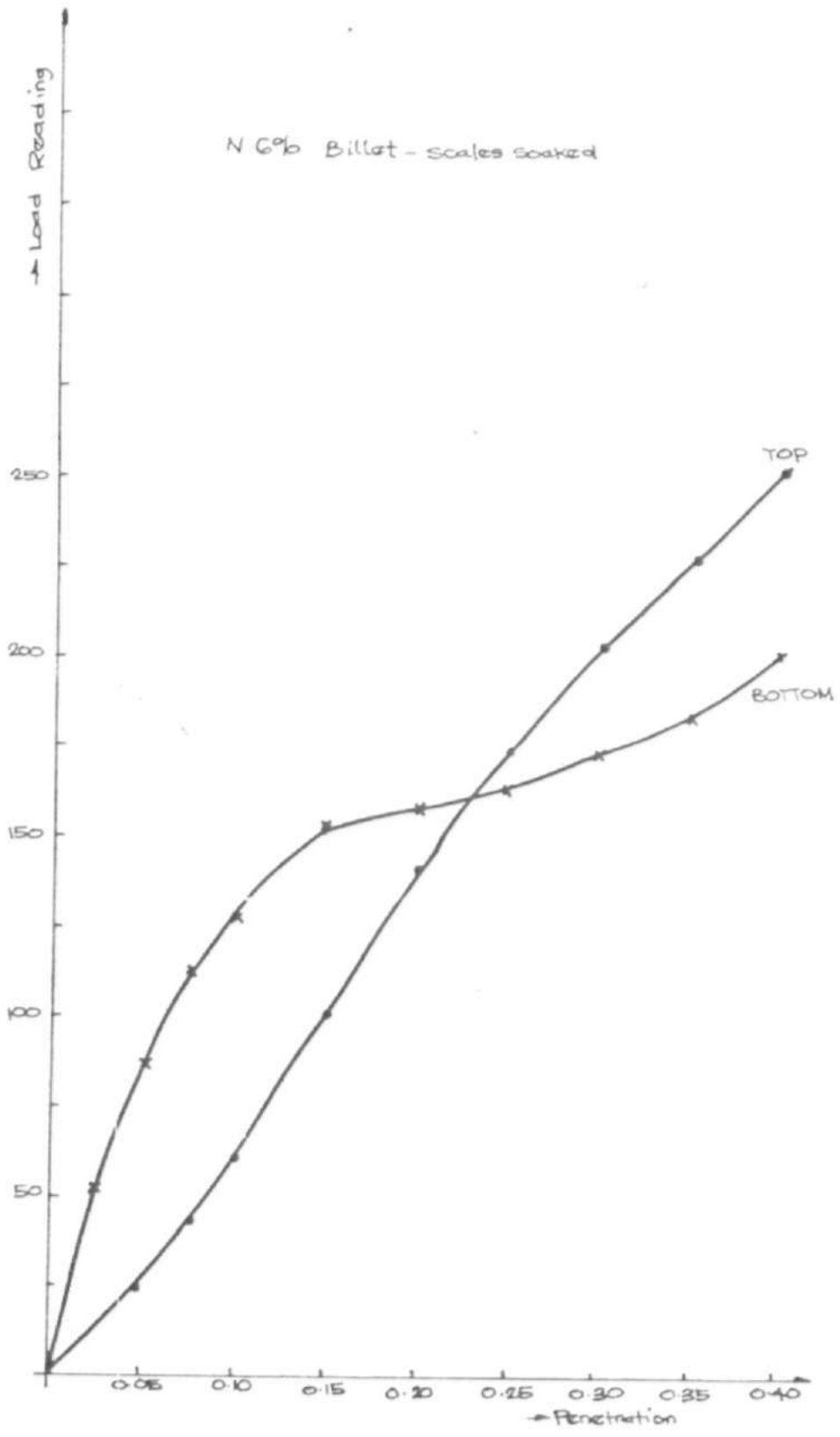

M 4% Billet scales unsoaked
Load Reading
350
300
250
200
150
100
50
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration


M 4% Billet- Scales Soaked
Load Reading
150
125
100
75
50
25
0
TOP
BOTTOM
0·05
0·10
0·15
0·20
0·25
0·30
0·35
0·40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	38	22	12	51
0.050	78	60	23	87
0.075	134	92	42	112
0.100	203	110	60	128
0.150	300	168	100	152
0.200	360	210	140	158
0.250	410	235	173	162
0.300	438	252	202	173
0.350	465	265	225	183
0.400	492	300	250	200
0.450	520	330	268	215
0.500	543	360	280	230
CBR %	23.13	13.49	9.0	12.34
Average	18.31		10.67	

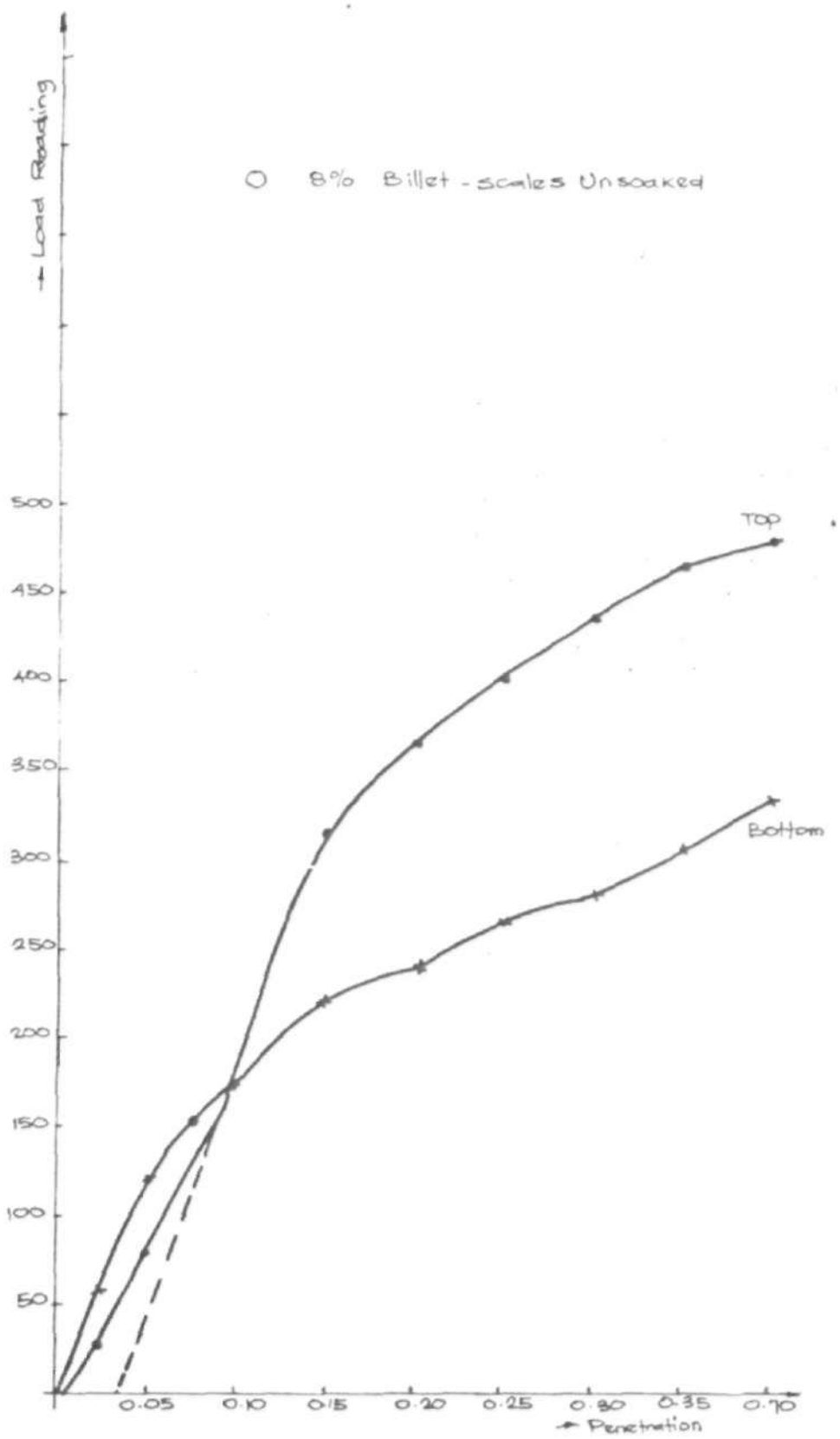
CBR RESULT FOR 6% Billet-Scales Stabilizer

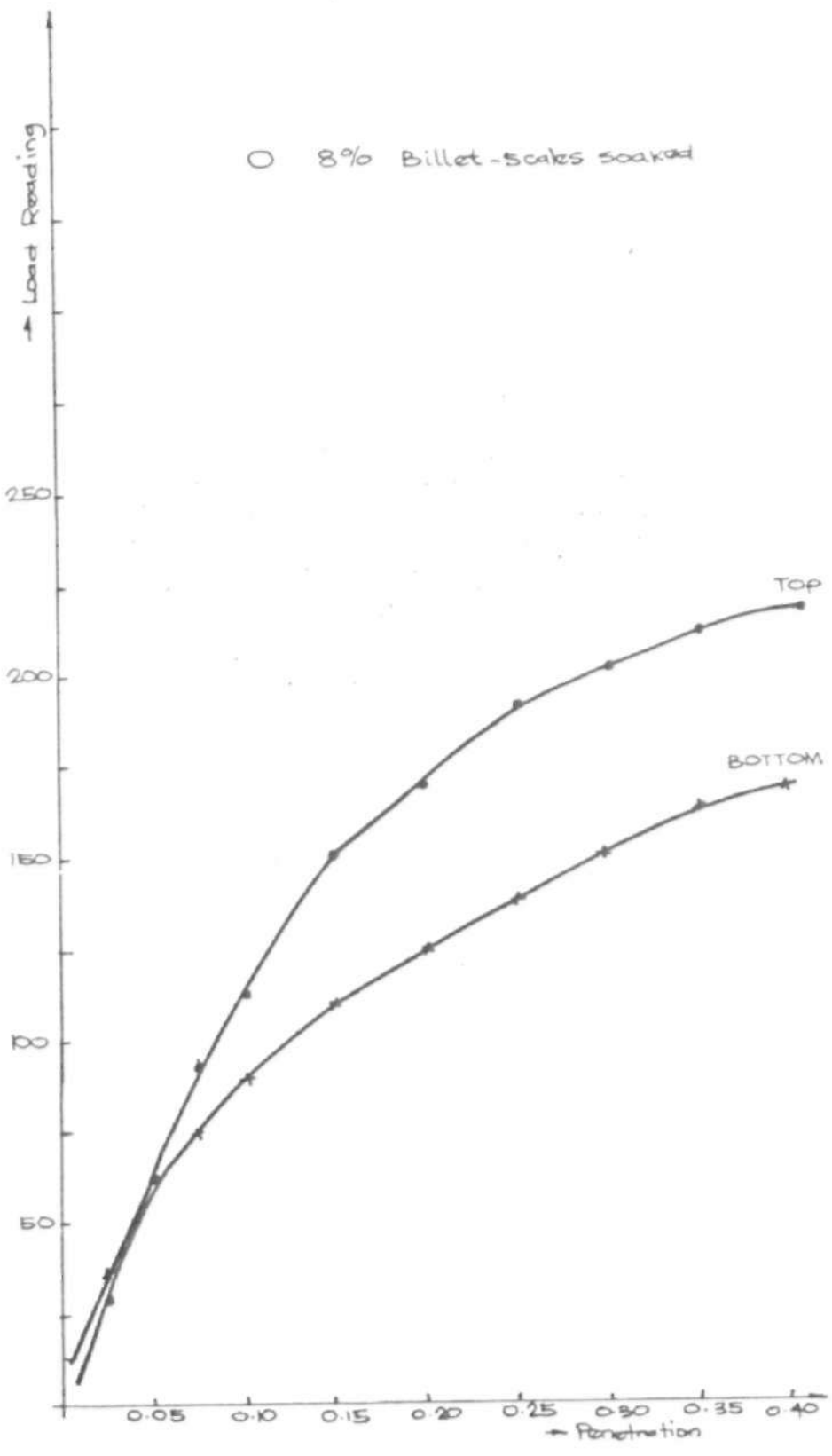

N 6% Billet - scales Unscoured
Load Reading
500
450
400
350
300
250
200
150
100
50
TOP
BOTTOM
0·00
0·10
0·15
0·20
0·25
0·30
0·35
0·40
Penetration


N 6% Billet - scales soaked
Load Reading
250
200
150
100
50
TOP
BOTTOM
0·05
0·10
0·15
0·20
0·25
0·30
0·35
0·40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	28	58	30	38
0.050	80	120	63	62
0.075	152	153	92	75
0.100	220	172	112	90
0.150	315	238	150	110
0.200	363	265	168	125
0.250	401	280	190	138
0.300	432	305	200	150
0.350	462	332	210	162
0.400	475	352	215	168
0.450	492	375	223	175
0.500	515	400	233	187
CBR %	20,24	16.56	10.79	8.67
Average	18.4		9.73	

CBR RESULT FOR 8% Billet-Scales..... Stabilizer

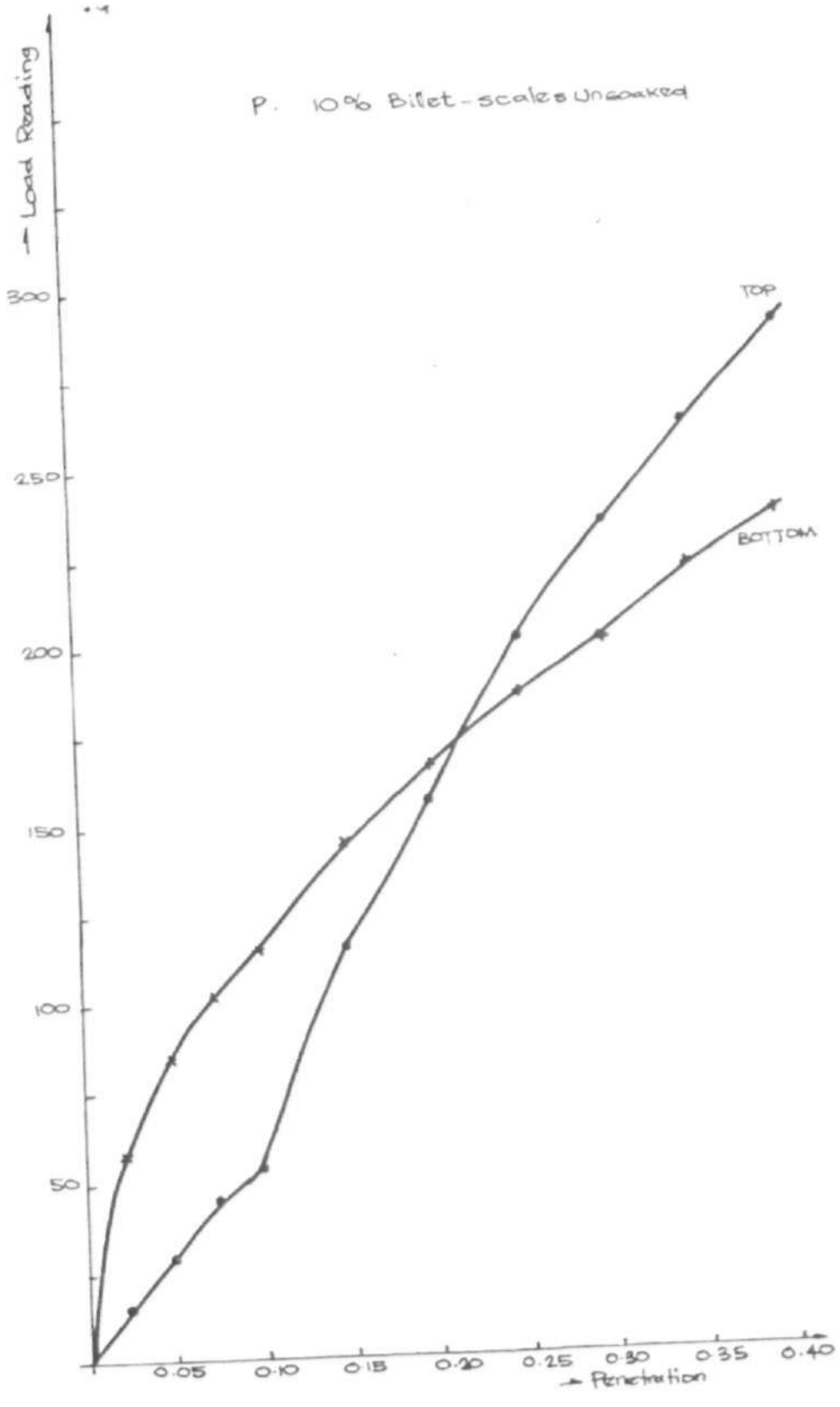

Load Reading
500
450
400
350
300
250
200
150
100
50
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.70
Penetration
Top
Bottom
O 8% Billet - scales Unsoaked


O 8% Billet-Scales soaked
Load Reading
250
200
150
100
50
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

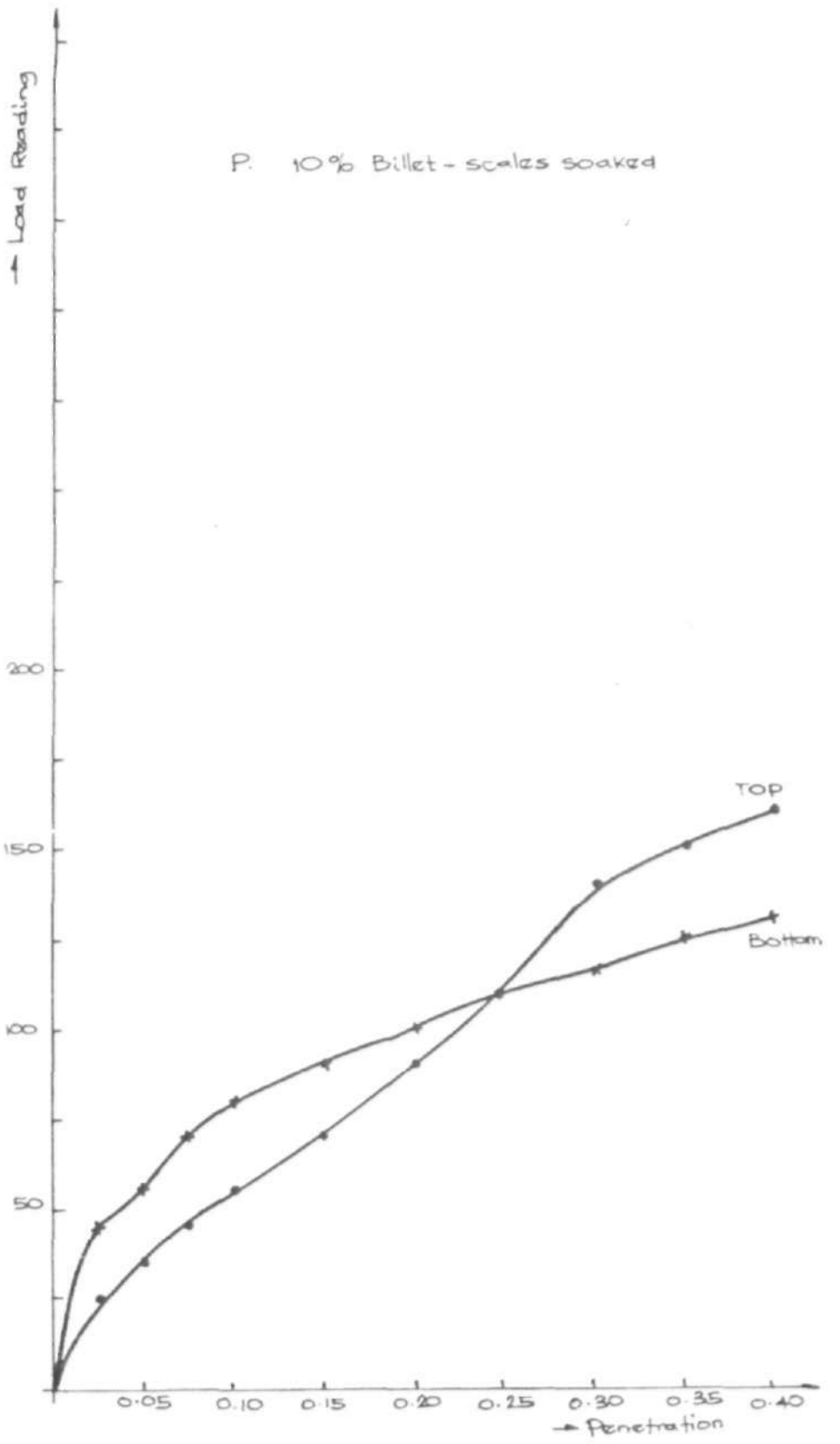
Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	15	58	25	45
0.050	28	85	35	55
0.075	45	103	45	70
0.100	54	115	55	80
0.150	115	145	70	90
0.200	155	165	90	100
0.250	200	185	110	110
0.300	233	200	140	115
0.350	260	220	150	125
0.400	287	235	160	130
0.450	318	250	170	139
0.500	330	273	180	143
CBR %	9.95	11.08	5.78	7.71
Average	10.52		6.75	

CBR RESULT FOR P 10% Billet-Scales ..... Stabilizer

P. 10% Billet - scales Unsoaked

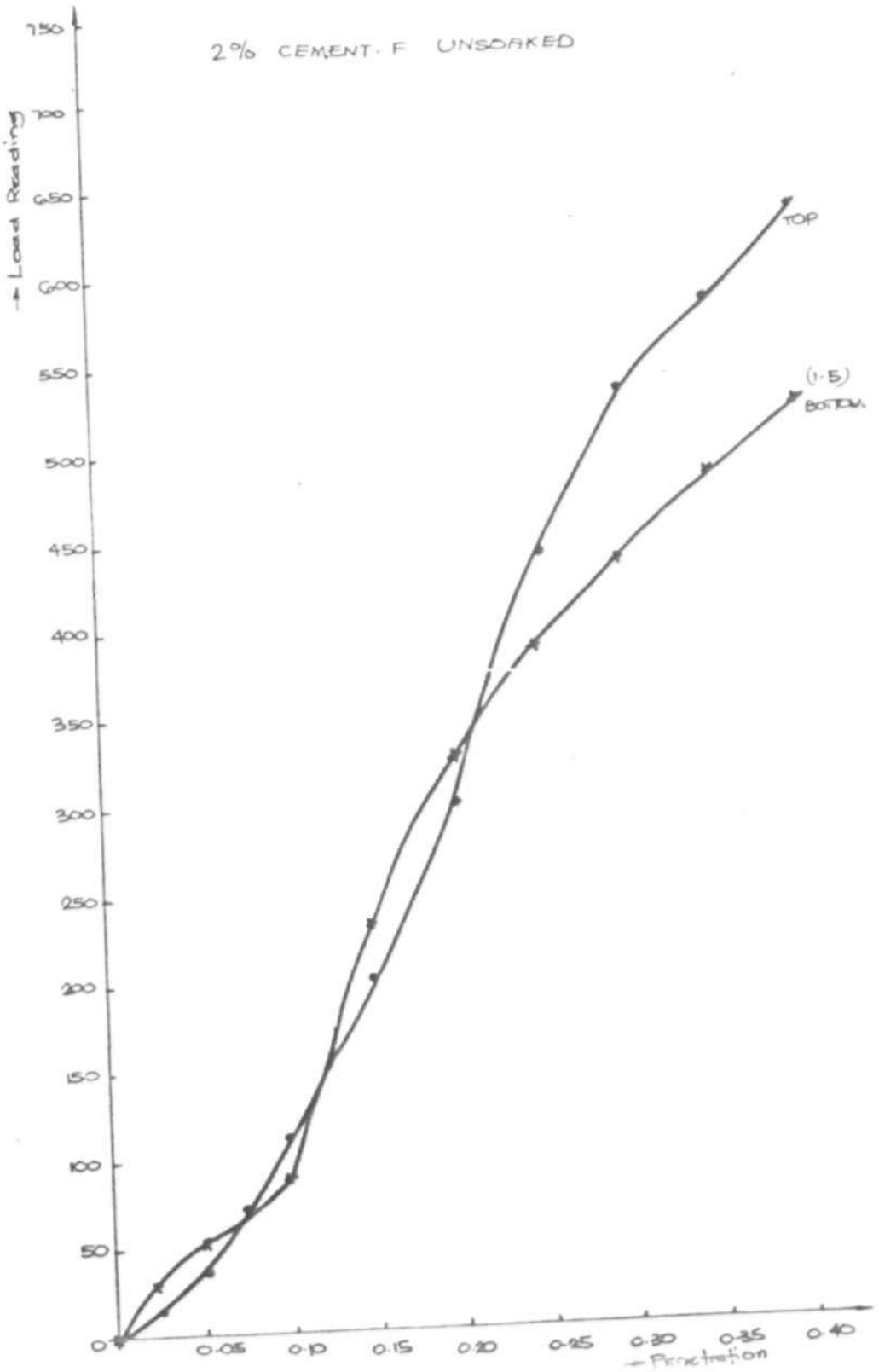


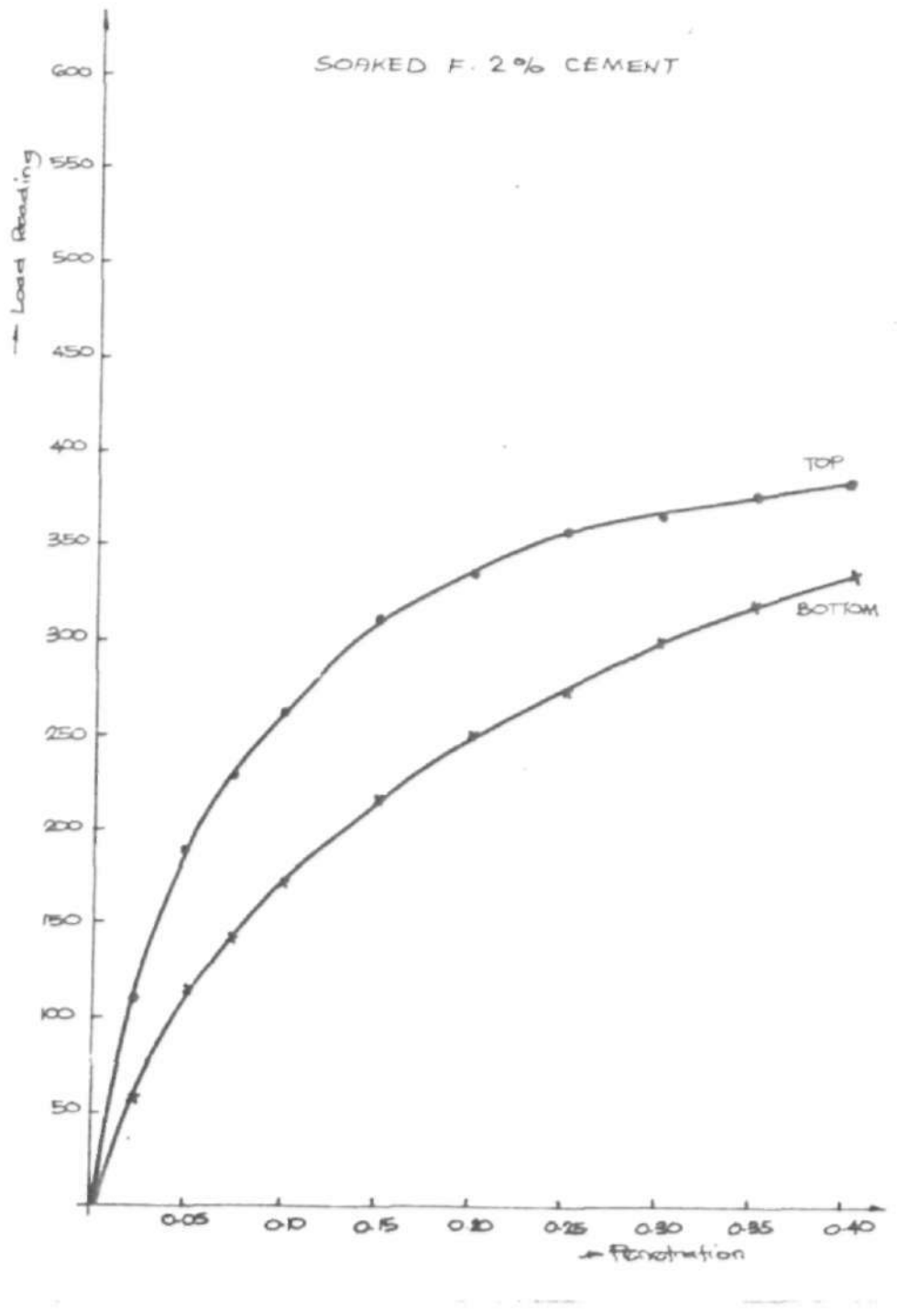
P. 10% Billet - scales soaked



Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	15	28	110	58
0.050	38	52	190	115
0.075	72	68	228	142
0.100	110	87	265	172
0.150	200	230	310	218
0.200	300	325	335	250
0.250	440	385	358	272
0.300	530	432	362	300
0.350	580	483	372	318
0.400	630	520	382	332
0.450	675	553	405	351
0.500	708	575	415	373
0. .				
CBR %	23.77	20.88	25.54	16.58
Average	22.33		21.06	

CBR RESULT FOR ..... F 2% ..... Cement Stabilizer

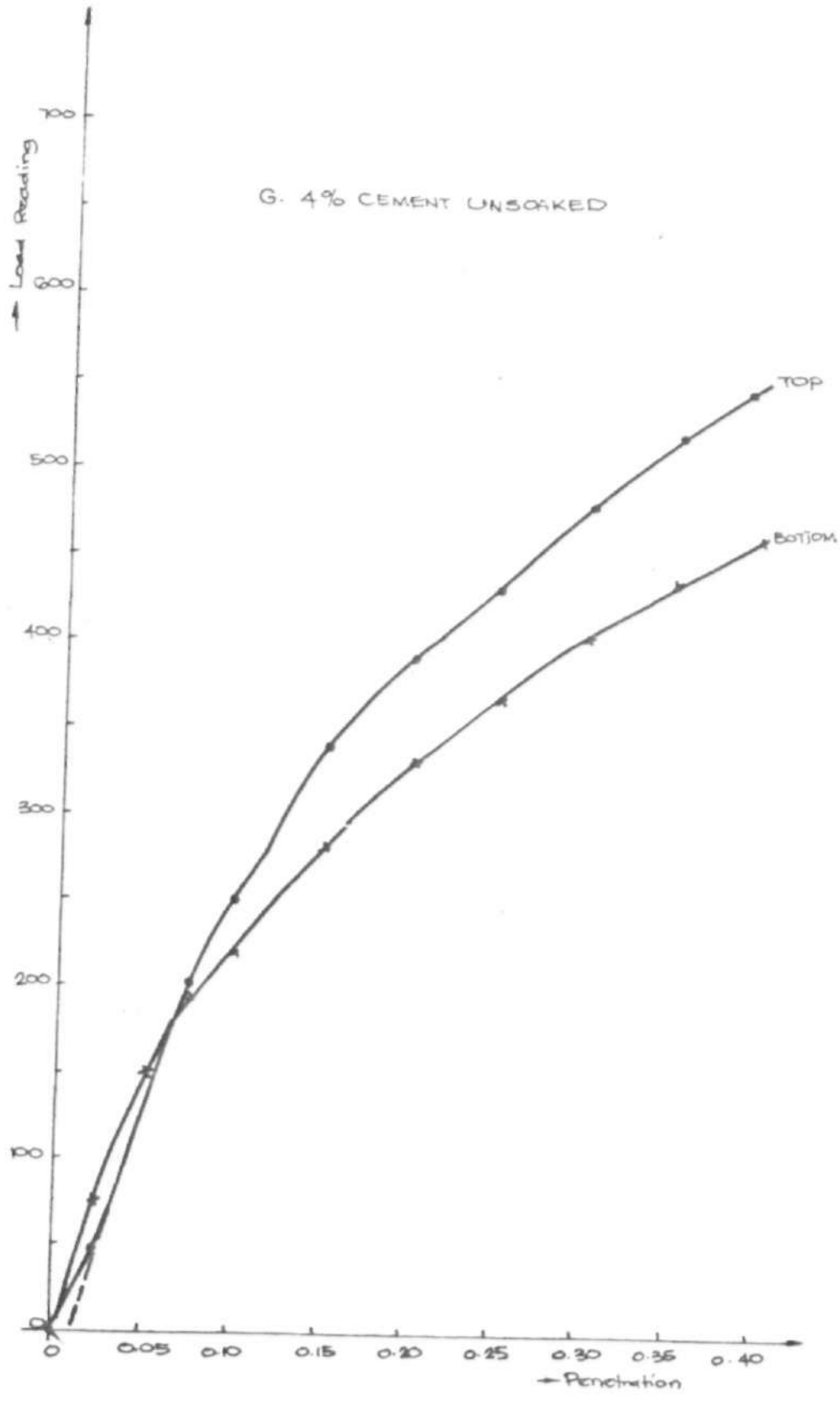

2% CEMENT. F UNSOAKED
Load Reading
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration
TOP
(1.5)
BOTTOM

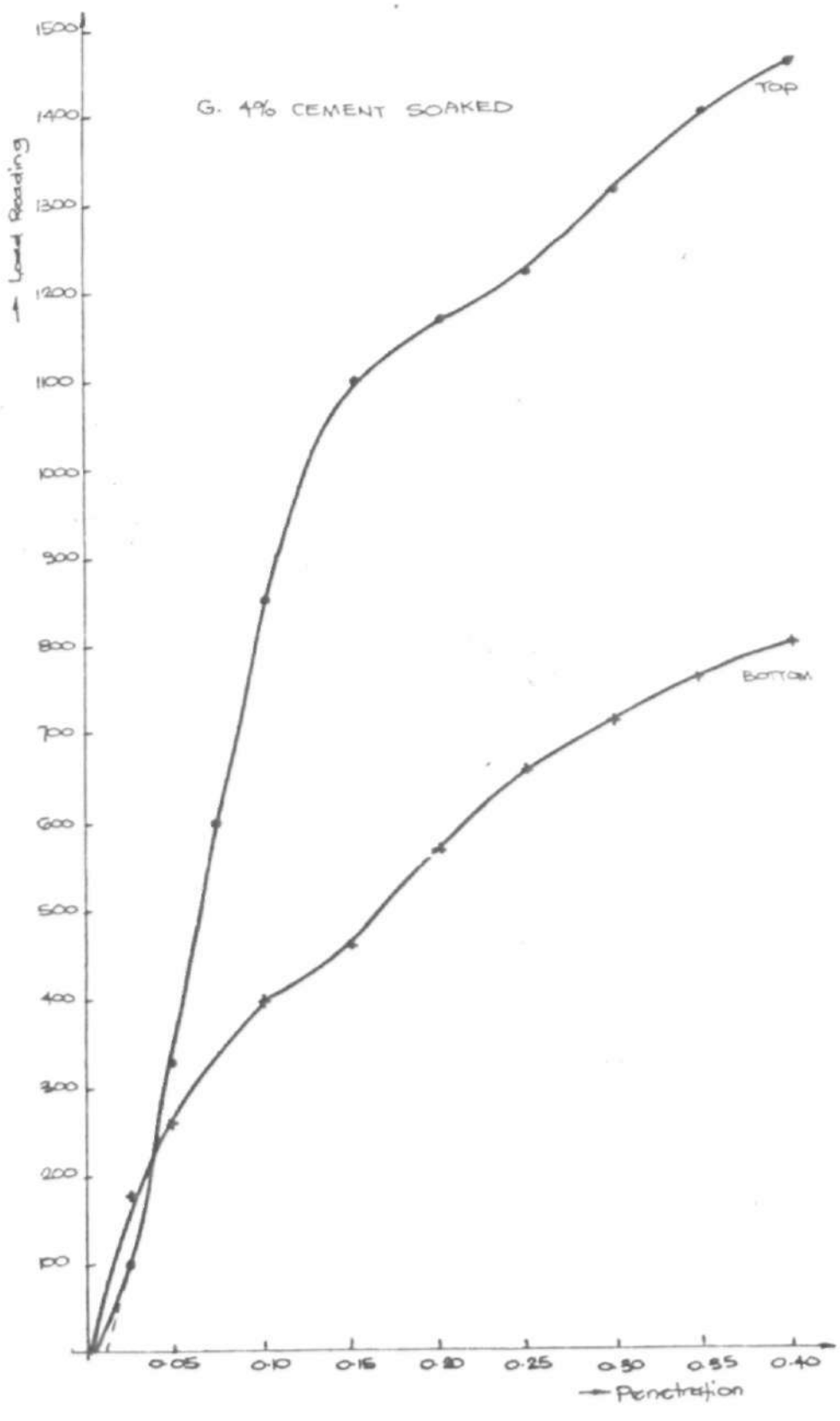

SOAKED F. 2% CEMENT
Load Reading
600
550
500
450
400
350
300
250
200
150
100
50
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	48	75	100	153
0.050	123	150	330	260
0.075	200	192	600	340
0.100	250	220	850	400
0.150	338	280	110	460
0.200	390	330	1170	570
0.250	430	365	1220	655
0.300	480	402	1312	710
0.350	520	435	1400	760
0.400	560	460	1460	800
0.450	580	490	1500	835
0.500	602	515	1600	865
CBR %	22.17	21.69	81.92	60.23
Average	21.69		60.23	

CBR RESULT FOR G 4% Cement ..... Stabilizer

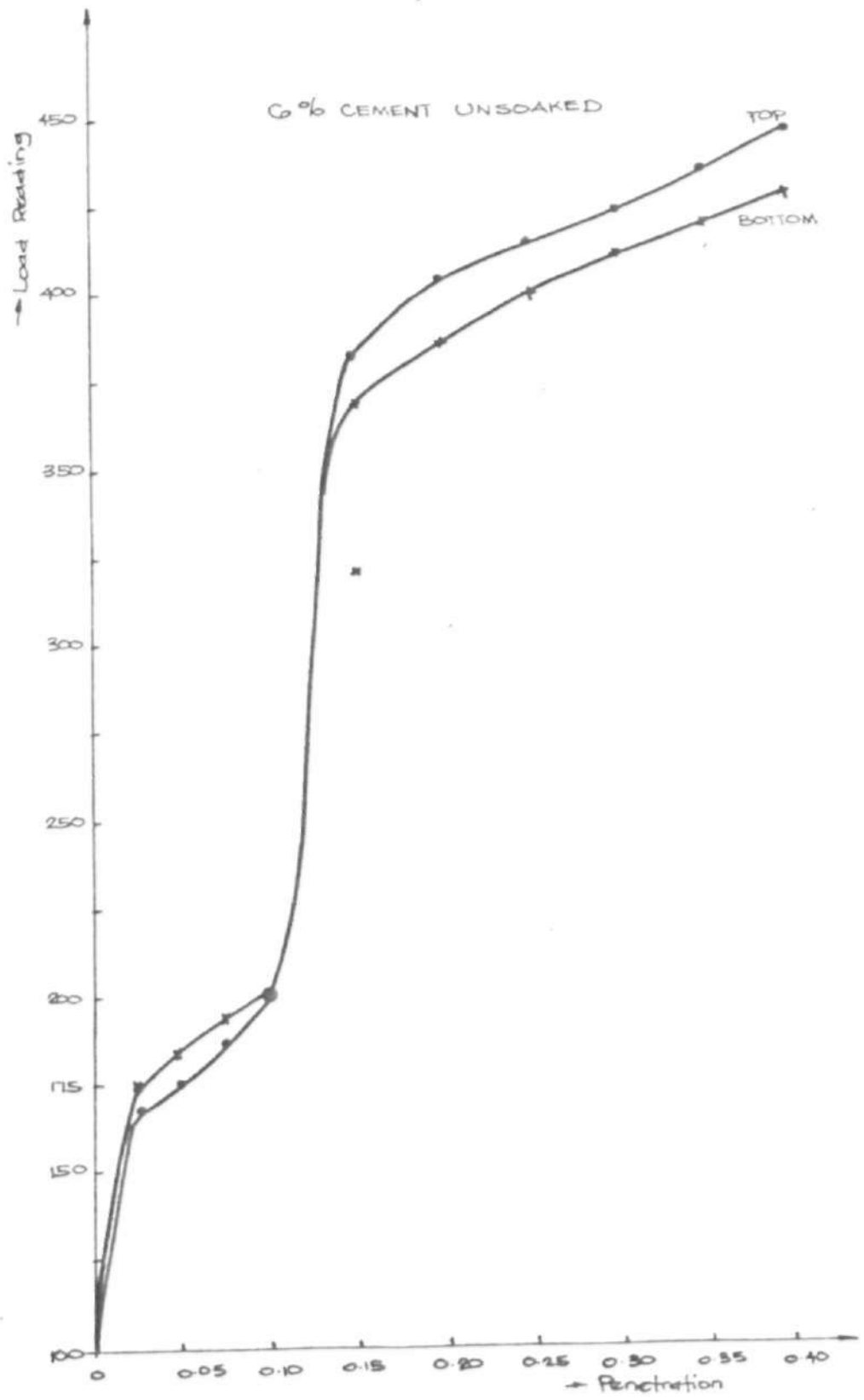
G. 4% CEMENT UNSOAKED

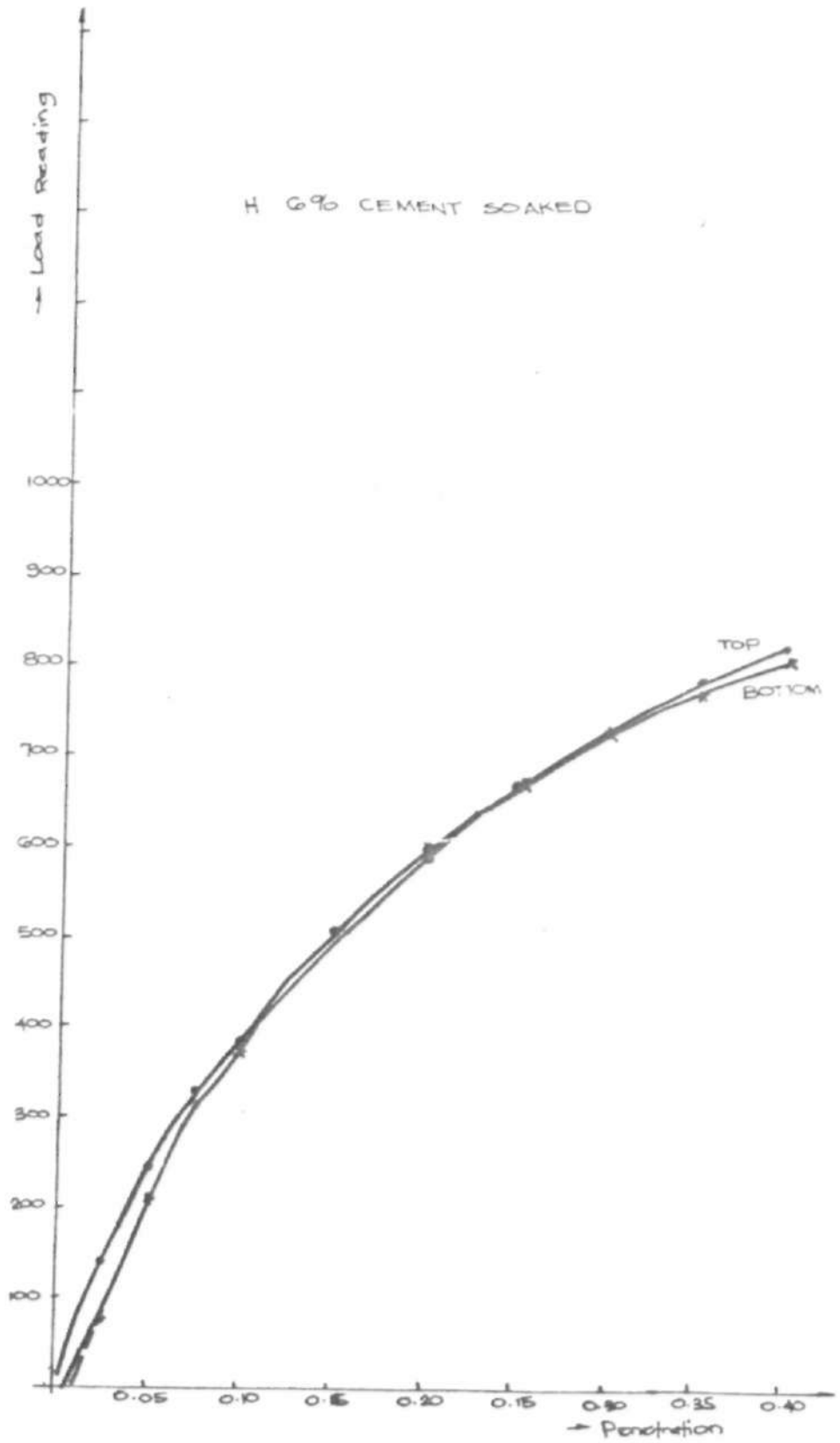



G. 4% CEMENT SOAKED
TOP
BOTTOM
Load Reading
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0·05
0·10
0·15
0·20
0·25
0·30
0·35
0·40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	12	18	140	73
0.050	20	27	248	210
0.075	32	35	325	315
0.100	45	42	380	373
0.150	72	60	510	510
0.200	93	75	590	600
0.250	102	87	670	670
0.300	112	100	730	725
0.350	123	108	783	768
0.400	130	115	820	810
0.450	135	123	870	843
0.500	140	132	920	875
CBR %	25.98	24.80	36.62	39.51
Average				

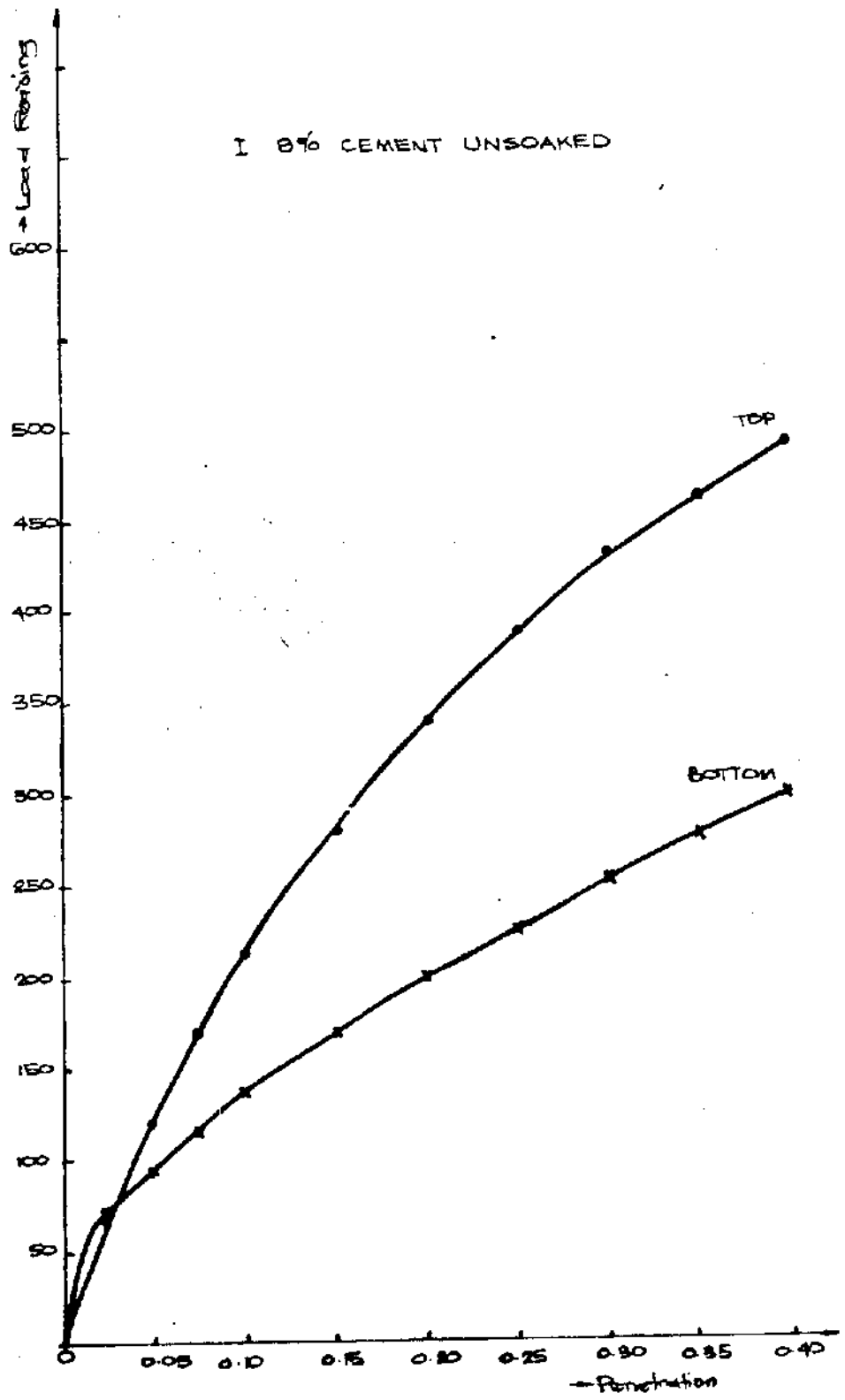
CBR RESULT FOR H..6%.Cement..... Stabilizer

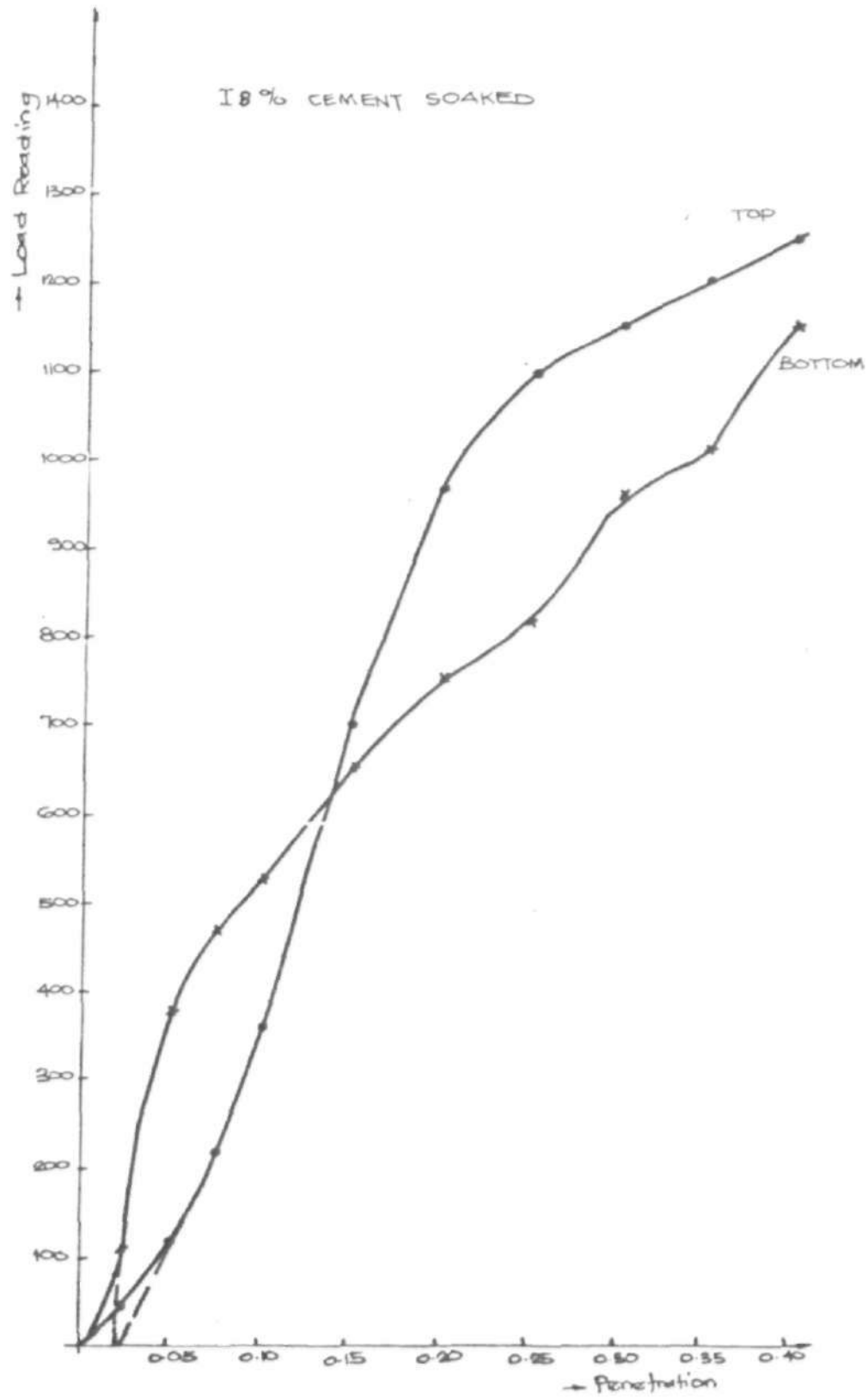

6% CEMENT UNSOAKED
TOP
BOTTOM
Load Reading
450
400
350
300
250
200
175
150
100
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration


H 6% CEMENT SOAKED
Load Reading
1000
900
800
700
600
500
400
300
200
100
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	70	75	45	110
0.050	120	95	118	380
0.075	170	115	220	470
0.100	215	139	360	530
0.150	280	170	700	650
0.200	340	200	968	753
0.250	387	225	1098	815
0.300	430	254	1150	965
0.350	460	275	1200	1010
0.400	490	300	1250	1150
0.450	510	330	1350	1180
0.500	540	350	1520	1220
CBR %	21.84	13.40	66.18	56.38
Average	17.62		61.28	

CBR RESULT FOR I 8% Cement ..... Stabilizer

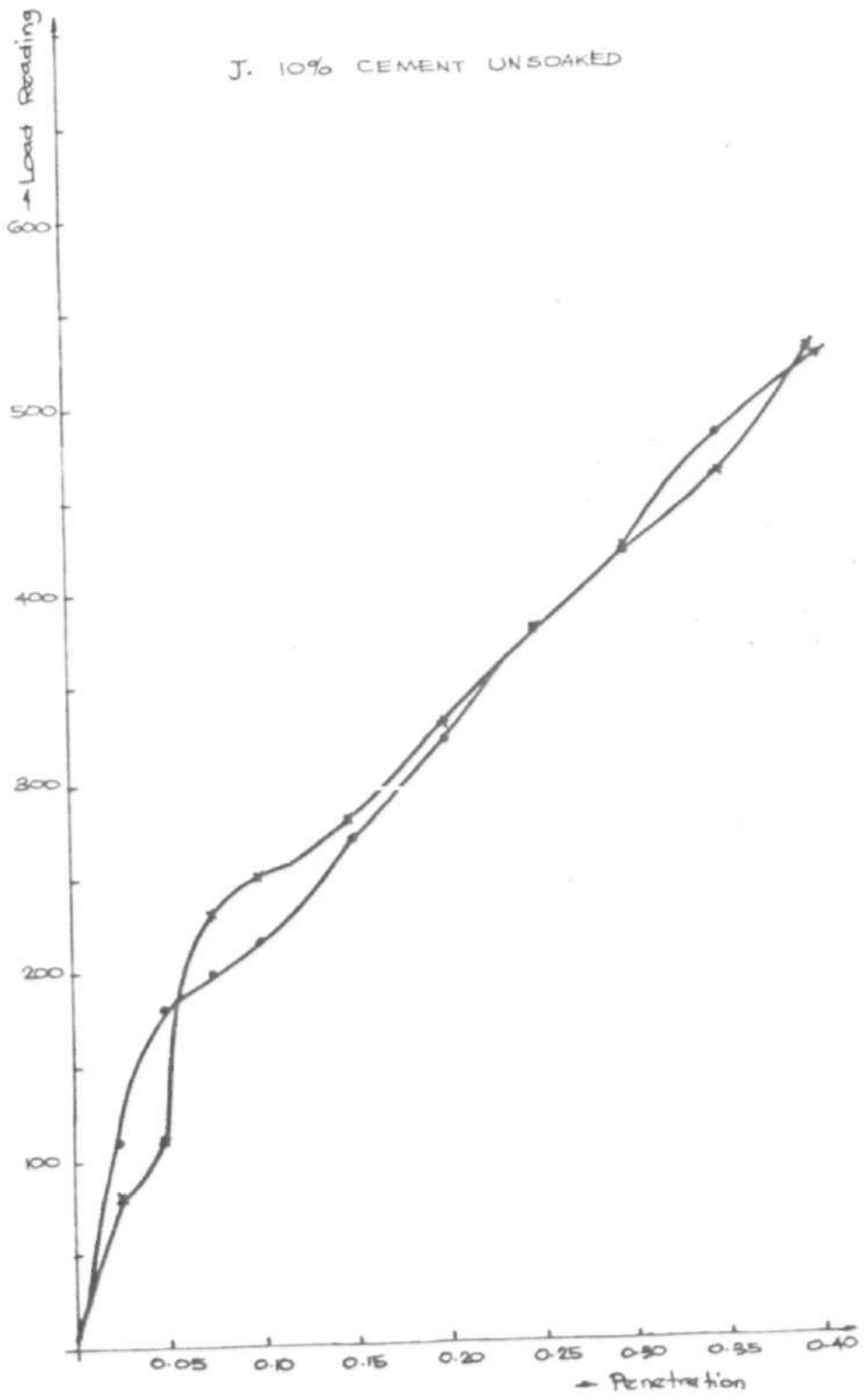

I 8% CEMENT UNSOAKED
Load Reading
600
500
450
400
350
300
250
200
150
100
50
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration
TOP
BOTTOM

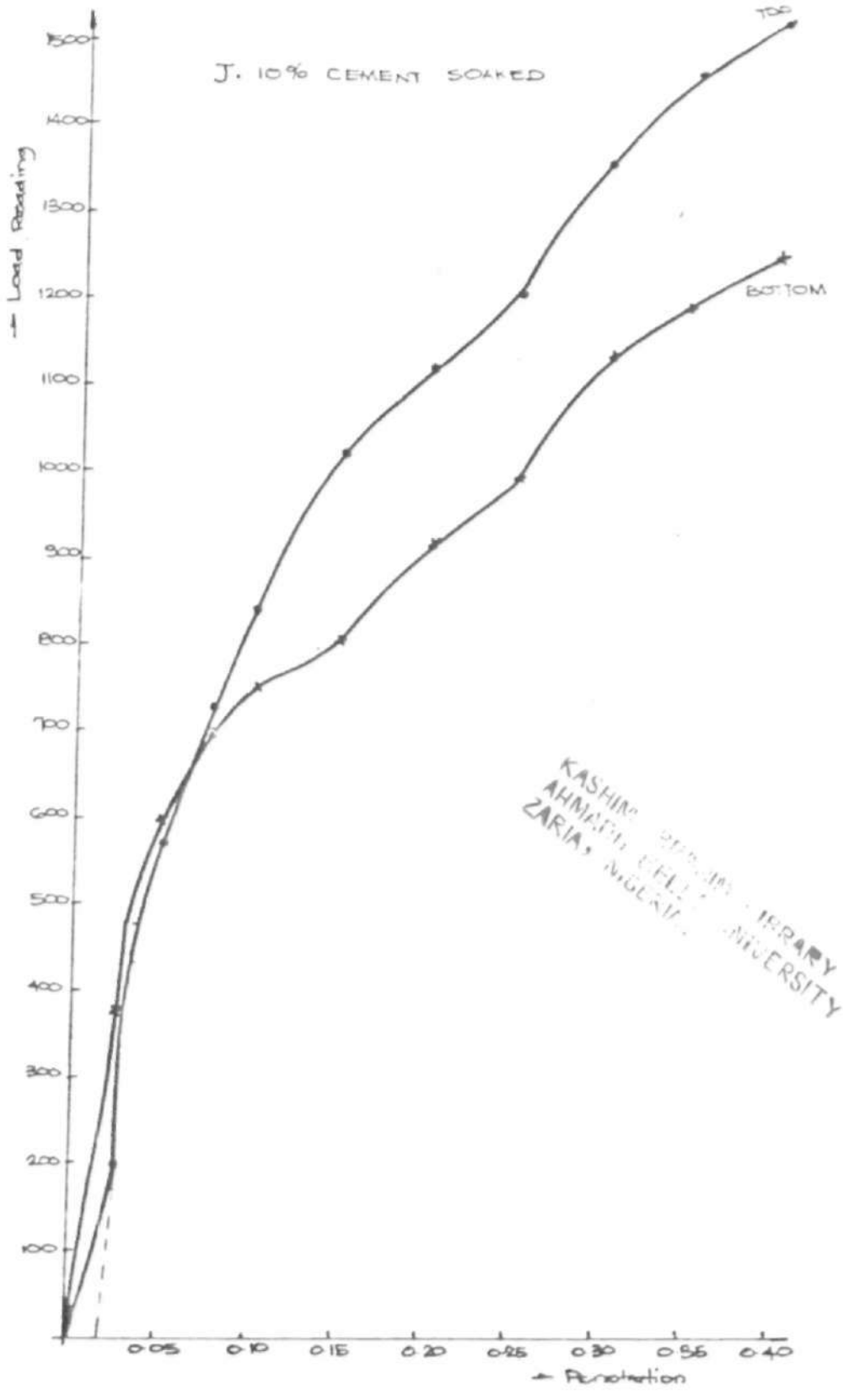

18% CEMENT SOAKED
Load Reading
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
TOP
BOTTOM
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Penetration

Penetration (ins.)	LOAD INDICATION			
	UNSOAKED		SOAKED	
	TOP	BOTTOM	TOP	BOTTOM
0.000	0	0	0	0
0.025	110	81	200	375
0.050	180	110	570	600
0.075	200	230	730	700
0.100	215	250	840	750
0.150	270	280	1020	800
0.200	320	330	1120	920
0.250	380	380	1200	990
0.300	420	420	1350	1140
0.350	480	460	1460	1193
0.400	520	525	1530	1250
0.450	560	580	1600	1300
0.500	600	630	1672	1350
CBR %	20.72	24.09	80.95	72.23
Average	22.41		76.59	

CBR RESULT FOR J 10% Cement..... Stabilizer

J. 10% CEMENT UNSOAKED





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