AVAILABILITY OF NATURAL GRAVEL FOR ROAD CONSTRUCTION IN GHANA

by

George Kodwo Addison, BSc Civil (Hons)

KNUST

A Thesis Submitted to the Department of Civil Engineering,

Kwame Nkrumah University of Science and Technology

in Partial Fulfilment of the Requirement for the Award of the Degree

of

MASTER OF SCIENCE

Faculty of Civil and Geomatic Engineering

College of Engineering

June 2008

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CERTIFICATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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(Head of Dept. Name) Signature Date

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Finally I wish to thank the family and my wife Obaa Yaa Addison (Mrs) for her prayers, encouragement and assuming the fatherly role of our son Kodwo Sekyi Addison while I was away undertaking this course.

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LIST OF ABBREVIATIONS

AADT	Average Annual Daily Traffic
AR	Ashanti Region
BAR	Brong Ahafo Region
CBR	California Bearing Ratio
CR	Central Region
DFR	Department of Feeder Roads
DUR	Department of Urban Roads
ER	Eastern Region
F	Failed
GAR	Greater Accra Region
GHA	Ghana Highway Authority
LL	Liquid Limit
MoT	Ministry of Transportation
MRH	Ministry of Road and Highways
NC	Non Classified
NA	Not Available
NR	Northern Region
P	Passed
PI	Plasticity Index
PL	Plastic Limit
TRL	Transport Research Laboratory
UER	Upper East Region
UWR	Upper West Region
WR	Western Region

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ABSTRACT

Most road pavements in Ghana have for many years been built of natural gravel as the subbase and base layers. Natural gravel are the most economical material for road construction when available within economic haulage distances. However, there has been a gradual shift to the use of a blend of natural gravel and other materials (stabilization) or crushed stone as the layer materials for subbase and base. In addition, various studies have been done to improve the engineering properties of natural gravel underscoring the difficulty of finding suitable material for construction in Ghana. However the extent of the problem is unknown.

This study evaluated some material properties (CBR, grading and Atterberg limits) of natural gravel samples from 454 borrow pits distributed throughout the country for their suitability or otherwise for road construction as a subbase, base and Otta seal. Each material property was compared with G30, G40, G60 and G80 MoT specifications. The ones meeting the criteria were denoted as passed or failed if otherwise. The results showed that it is difficult getting natural gravel meeting the specification for G80 base material. However, there is significant improvement when a relaxed specification of G60 is used. This indicated grading plays a very important part in deciding whether a natural gravel material meets specification or not. Generally Western Region had the greatest difficulty of meeting grading requirement. The overall proportion of samples meeting the requirements of subbase and base are 26% and 2% respectively. It is almost impossible to find a natural gravel pit meeting the requirements of Otta seal without processing. Most natural gravel in the country will need two cycles of screening for them to meet the gradation requirement for Otta seal.

TABLE OF CONTENTS

CERTIFICATION ii

ACKNOWLEDGEMENTS iii

LIST OF ABBREVIATIONS iv

ABSTRACT v

TABLE OF CONTENTS vi

APPENDICES ix

LIST OF TABLES x

LIST OF FIGURES xii

CHAPTER ONE 1

1 INTRODUCTION 1

1.1 Importance of Road Transport to National Economy 1

1.2 Structure of Road Pavement 1

1.3 Problem Definition 2

1.4 Research Objectives 3

1.5 Justification 3

1.6 Scope of Work 5

CHAPTER TWO 6

2 LITERATURE REVIEW 6

2.1 Formation of Lateritic Soils 6

2.2 Classification of Laterites 8

2.2.1 The Silica to Sesquioxide Ratio 8

2.2.2 The Chemical Weathering Index 9

2.2.3 The TRL Classification System 10

2.3 Natural Gravels of Ghana 11

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2.3.1 Formation 11
2.3.2 Classification 11
2.3.3 Distribution 13
2.3.4 Engineering Characteristics 16
2.3.4.1 Particle-size Distribution 16
2.3.4.2 Plasticity Index 17
2.3.4.3 California Bearing Ratio (C.B.R.) 18
2.3.4.4 Aggregate Strength 19
2.4 Ministry of Transportation Classification of Natural Gravel in Ghana 21
Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 2006, MOT, Ghana 23
2.5 Requirement of Aggregates for Otta seal 24
2.5.1 Grading 24
2.5.2 Plasticity Index 26
2.5.3 Aggregate Strength 26
2.6 Logistic Regression Model 27
2.6.1 Selection of Model 27
2.6.2 The Logit Model 28
CHAPTER THREE 31
3 METHODOLOGY 31
3.1 Data Collection 31
3.2 Data Entry 31
3.3 Analysis of Data 32
3.4 Locations of Gravel Samples 33
CHAPTER FOUR 35

4 RESULTS AND DISCUSSION 35
4.1 Distribution of Gravel Pits 35
4.2 Natural Gravel Subbase Material 36
4.2.1 Specification 36
4.2.2 Individual Parameters 37
4.2.3 All Parameters 41
4.3 Natural Gravel Base Material 43
4.3.1 Specification 43
4.3.2 Individual Parameters 44
4.3.3 All Parameters 49
4.4 Natural Gravel Material Meeting Requirement for Otta seal 56
4.4.1 Specification 56
4.4.2 Individual Parameters 56
4.5 Probabilities 58
CHAPTER FIVE 62
5 CONCLUSIONS AND RECOMMENDATION 62
5.1 Conclusions 62
5.2 Recommendation 64
REFERENCES 65

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KUMASI-GHANA

APPENDICES

Appendix A: MoT Specification for Subbase and Base Material.....69

Appendix B: Locations of Natural Gravel.....72

Appendix C: Comparing Grading, CBR and Atterberg Limits of Natural Gravels with MoT G40 Subbase Requirements 88

Appendix D: Comparing Grading, CBR and Atterberg Limits of Natural Gravels with MoT G80 Base Requirements 102

Appendix E: Comparing Grading and PI of Natural Gravels with Otta Seal Requirements 116

Appendix F: Comparing Grading, CBR and Atterberg Limits of Natural Gravels with MoT G60 Base Requirements.....131

Appendix G: Comparing Grading, CBR and Atterberg Limits of Natural Gravels with MoT G40 Base Requirements.....145

Appendix H: Grading of Natural Gravel on MoT Subbase envelope.....160

Appendix I: Grading of Natural Gravel on MoT Base envelope..... 170

Appendix J: Grading of Natural Gravel on Otta seal envelope.....180

KNUST

LIST OF TABLES

Table 1.1 Test Results from Konongo – Kumasi Road Project (Attah 2006) 4

Table 2.1 Silica to Sesquioxide Ratio Classification for Laterirte (Morin et al, 1971) 9

Table 2.2 Relationship between CWI and laterite classification (after Sueoka, 1900 as referenced by Ampadu, 2007) 9

Table 2.3 TRL laterite classification (after Charman, 1995 as referenced by Ampadu, 2007) 10

Table 2.4: Physical features and mechanical characteristics of laterite gravels of Ghana (De-Graft Johnson et al., 1969) 12

Table 2.5 : Rating of gravel aggregates (Bhatia and Hammond, 1970) 20

Table 2.6 :Grading requirement for Subbase and Base 22

Table 2.7: CBR, Grading, Atterberg Limit and 10% fines requirement for subbase and base 23

Table 2.8: Grading requirement for Otta seal (Overby, 1999) 25

Table 2.9: Aggregate strength and PI requirement for Otta seal 27

Table 2.10: Otta Seal requirements for PI and Grading 27

Table 3.1: Typical spread sheet 33

Table 4.1: Distribution of samples from the 3 road agencies 35

Table 4.2: Regional Distribution of number of secondary data 36

Table 4.3:MoT requirements for subbase material 36

Table 4.4: Number Gravel pits passing or failing various requirements of G40 specification 37

Table 4.5: Number Gravel pits passing or failing various requirements of G30 specification 38

Table 4.6: Availability of Material Meeting G-40 Specification 39

Table 4.7: Availability of Material Meeting G-30 Specification 40

Table 4.8Regional Distribution of number of natural gravel pits passing or failing the requirements of G40 specification.....42

Table 4.9: Regional Distribution of number of natural gravel pits passing or failing the requirements of G30 specification.....43

Table 4.10 :MoT rcquirements for Basc Material 44

Table 4.11: Number of Gravel pits passing or failing various requirements for G80 specifications 45

Table 4.12: Number of Gravel pits passing or failing various requirements for G60 specifications 46

Table 4.13: Availability of Material Meeting G-80 Specification 47

Table 4.14: Availability of Material Meeting G-60 Specification 48

Table 4.15: Rcgional Distribution of number of gravel pit passing or failing the requirements of G80 specification.....50

Table 4.16: Regional Distribution of number of gravel pit passing or failing the requirements of G60 specification.....50

Table 4.17: Requirements for Otta Seal 56

Table 4.18: Availability of Material meeting Otta Seal Specification 57

Table 4.19: Samples passing after processing.....58

Table 4.20: Results of all 4 parameters of natural gravel in the NR compared to G80 base specification (From Appendix D1).....59

Table 4.21: Output from the logistic Regression Model using X1, X2, X3 and X4. .60

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LIST OF FIGURES

Figure 1.1 Typical section through a trunk road showing different pavement layers. .1

Figure 2.1 Generalised world map showing the distribution of laterite soils.....8

Figure 2.2: Simplified geological map of Ghana (Gidigasu, 1972) 14

Figure 2.3: Generalised distribution of quartzitic gravels and gravelly soils in Ghana (Gidigasu, 1972). 15

Figure 2.4: Particle-size distribution envelopes typical of concretionary laterite and quartzitic gravels identified in West Africa superimposed on MOT grading curve for sub base and base (Gidigasu, 1972).....16

Figure 2.5: Average relation between the clay size content and plasticity index for some residual laterite soils (Gidigasu, 1972, as referenced by Gidigasu, 1976).....18

Figure 2.6: Grading envelopes for G80/G60/G40/G30 material 22

Figure 2.7: Open, medium and dense grading envelope for Otta seal (Overby and Pinard, 2007).....26

Figure 2.8 : Logistic response function 29

Figure 3.1: Locations of gravel samples.....34

Figure 4.1: Percentages of gravel pits meeting the MoT requirement for G80.....52

Figure 4.2: Percentages of gravel pits meeting the MoT requirement for G60.....53

Figure 4.3: Percentages of gravel pits meeting the MoT requirement for G40.....54

Figure 4.4: Percentages of gravel pits meeting the MoT requirement for G30.....55

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CHAPTER ONE

1 INTRODUCTION

1.1 Importance of Road Transport to National Economy

US President John F Kennedy is reported to have said "it is not the wealth of a nation that builds roads, but the roads that build the wealth of a nation." This shows that the statesman realized that for any country to have a rapid economic growth and social development there is the need to have an efficient and reliable transport system. Over the last 50 years, roads have been the backbone of Ghana's freight and passenger transport system with road networks continuing to grow rapidly throughout most of this period. In Ghana, the road network totals over 63,000km in length and accounts for 96-98% of both freight and passenger transport (MRT 2004). There is the need to ensure that roads in the country are well constructed with the required materials to avoid premature failures.

1.2 Structure of Road Pavement

The structure of a typical road pavement is made up of basically 4-layers which are the subgrade, subbase, base and a wearing course as shown in the Figure 1-1. Each layer material should meet the required specification before it can be used for construction.

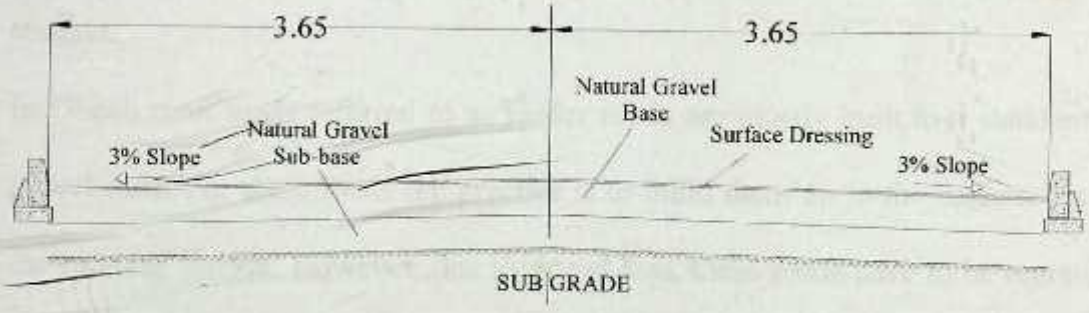

Figure 1.1 Typical section through a trunk road showing different pavement layers

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The subgrade forms the foundation of the pavement. It may consist of the insitu material, where the latter is to bear the load transmitted onto it or it may consist of transported material where the insitu material needs to be strengthened in order to carry applied loads. The sub-base and/or base material for most pavements in Ghana have for many years, been built of natural gravel.

1.3 Problem Definition

It is becoming increasingly difficult to find natural gravel meeting the required specification for subbase and base. This difficulty may have accounted for some pavement failures in the country. For example, the Anhwiankwanta – Cape Coast Road deteriorated just a year after construction. It is believed that one possible reason for the failure was the use of subbase and base material that did not meet the required specification (Grant et al 1996).

The difficulty of finding suitable natural gravel sub-base and base materials has also led to a gradual shift to the blending of natural gravel with other materials or the use of crushed stone base in recent times. For example, on the Ejisu-Bekwai Road Project a blend of natural gravel and crushed stone was used as the base material (Contract Document of Upgrading of Bewkai- Kuntunase- Ejisu). This also prompted various studies for example Attah (2006) into the effect of quarry dust as a mechanical stabilizing agent on selected geotechnical properties of lateritic gravel for road construction. However, the extent of the problem has not been systematically studied.

In Ghana rural roads referred to as feeder roads are mostly built to a standard of a gravel road. For these roads the practice is to build them up to the subbase level as the running surface. However, due to gravel loss, these roads have to be regravelled almost every 5 years. This adds to the road maintenance costs thus increasing the life cycle cost of unsurfaced roads and further also contributing significantly to fast

depletion of gravel deposits suitable for road construction in the country. It has been shown that providing appropriate surfacing is a more economical approach (Oloo et al, 2003). Many feeder roads however, are low volume roads with ADT less than 500 Veh/day making it uneconomical to apply the conventional chip seals for such roads. A less costly alternative for sealing of such low volume roads is the Otta Seal technology (Oloo et al, 2003) which allows the use of graded natural gravel containing fines. However, studies by Braimah (2007) have shown that it is almost impossible to find natural gravel meeting Otta Seal gradation requirement. In his studies all the 163 samples did not meet the specification and required at least one or two cycles of screening to generate sufficient quantities. Again, the extent of the difficulty of finding natural material meeting Otta seal specification has not been investigated.

1.4 Research Objectives

The overall objective of the study is to determine the extent of the problem of non-availability of suitable natural gravel for road pavement construction as measured by the probability of a gravel deposit not meeting the specification.

Specifically the objective is to

1. Catalogue properties of gravel material from gravel pits in different parts of the country.
2. Determine the probability that the selected properties will meet the specification individually for subbase, base and Otta seal.
3. Display graphically the results to depict the distribution across the country.

1.5 Justification

The study is justified by the fact that

1. Natural gravel is an important road construction material, its availability at economic haulage distances from construction fronts or otherwise can

make a difference in project costs. It is, therefore, necessary to have information on the availability of natural gravel to facilitate planning of road works.

2. The results of test on natural gravel material over an almost 15 km stretch of road on the Konogo – Kumasi Road project showed that at each chainage one or more of the required specification were not met (Table 1.1). This phenomenon is not in isolation but occurs in several parts of the country. There have been various studies to improve the engineering properties again underscoring the difficulty of finding suitable material. However, the extent of the problem does not appear to have been quantified and therefore this study seeks to investigate the extent of the problem of non-availability of natural gravel in Ghana for road construction.

Table 1.1 Test Results from Konongo – Kumasi Road Project (Attah 2006)

BORROW PITS	GRADING TEST PERCENTAGE BY WEIGHT PASSING								ATTERBERG LIMITS		CBR TEST	COMMENTS TEST FAILED
	75 mm	37.5 mm	20 mm	10 mm	5 mm	2 mm	0.425 mm	0.075 mm	LL %	PI %	96hrs soaked 95% MDD	
CH 223+200	100	100	99	912	78	59	45	34	19	16	49	Grading, PI
CH 215+000	100	98	95	88	78	63	49	36	44	21	54	Grading, PI, LL
CH 225+100	100	100	100	97	84	65	49	36	45	20	39	Grading, PI, LL, CBR
CH 232+500	100	98	84	74	61	47	35	22	32	13	56	Grading
CH 234+600	100	92	90	84	72	53	401	32	38	18	44	Grading, LL

1.6 Scope of Work

The work involved in the study covered the following:

1. Literature review, which covered a review of literature on laterite gravel formation, Ministry of Transportation's specification for subbase and base, specification for Otta seals and logistic regression model for the analysis of probabilities
2. Assembly of secondary laboratory test results from Road Agencies and from Consultants of borrow pits for road projects from different parts of the country during project feasibility studies within the past decade.
3. The study also included the analysis of the results first in terms of index properties, and a search for a probability function to describe the probability that a gravel deposit will meet the specification for each of the layers of the road. The study also included plotting of the results of the probability distribution analysis on the map of Ghana for each of the three uses of natural gravel.

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CHAPTER TWO

2 LITERATURE REVIEW

2.1 Formation of Lateritic Soils

Laterite (derived from the Latin word later meaning brick) is a surface formation in hot and wet tropical areas which is enriched in iron and aluminium and develops by intensive and long lasting weathering of the underlying parent rock. Laterites are soils formed from the disintegration of rocks through the process of weathering and laterisation (secondary weathering). Parent rocks are broken down into soil through the process of physical and chemical weathering which takes place simultaneously. In physical weathering the rock is broken down by mechanical procesess such as abrasion, expansion and construction without change in the crystal structure of the products from the parent rock. The end products include gravel, sand, silt and clay. During chemical weathering, the minerals are attacked by water, oxygen, carbon dioxide, alkaline and acid materials dissolved in water. The various chemical processes which take place include hydration, hydrolysis, oxidation, solution and carbonation (Lutgens and Tarbuck, 1993 as referenced by Ampadu, 2007). The end products are clay minerals with a completely different crystalline structure from that of the parent rock.

The process of chemical weathering is favoured by warm humid climate, presence of vegetation and gentle slopes which are conditions common in the tropical and sub-tropical regions. Under favourable tropical conditions, the percolating rain water causes dissolution of primary rock minerals and decrease of easily soluble elements such as sodium, potassium, calcium, magnesium and silicon. This gives rise to a residual concentration of more insoluble compounds predominantly hydrated oxides of iron and aluminium called sesquioxides.

Increased concentration of sesquioxides due to loss of moisture results in the formation of insoluble precipitates. Further concentration and the subsequent hardening of the precipitates referred to as concretionary development lead to formation of laterites in the form of hard concretionary nodules in a soil matrix or a hardened layer depending on the extent of concentration of sesquioxides. Depending on the degree of concretionary development, the physical properties of laterites may vary from soil to rock-like material.

The availability of iron and aluminium minerals and or quartz within the parent rock affects the formation of laterite soil. When quartz is the main component in the parent rock, it remains in the weathering product as quartz grains leading to an end product granular in texture with laterite forming minerals, kaolinite and sesquioxides forming concretionary products around the quartz. Parent rocks rich in iron and aluminium minerals (eg. basic rocks) will facilitate the development of concretionary product (Charman, 1995; Fookes, 1997, as referenced by Ampadu, 2007). Nearly all kinds of rocks can be deeply decomposed by the action of high rainfall and elevated temperatures.

The iron oxides, goethite and hematite cause the red-brown color of laterites. In addition, the presence of oxides of iron and aluminum together with silica and kaolinite clay minerals in various different proportions gives laterite the distinct ochre, yellow and purple colour. Laterite covers have mostly a thickness of a few meters but occasionally they can be much thicker. Figure 2.1 below is the geographical distribution of laterites worldwide.

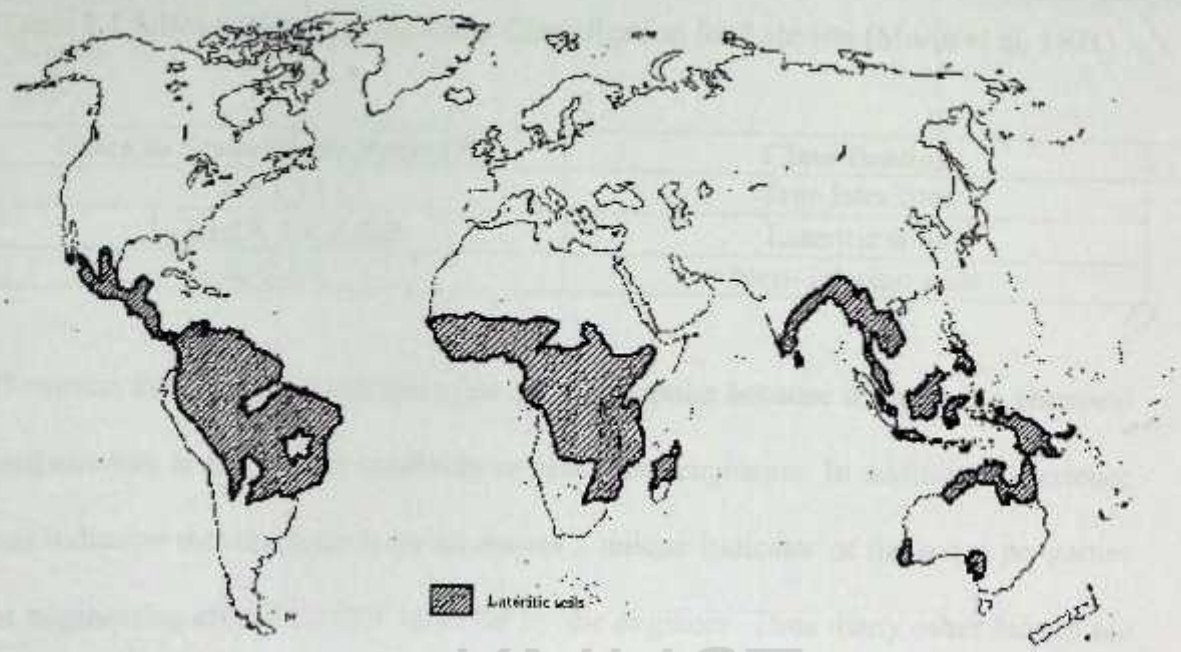

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Figure 2.1 Generalised world map showing the distribution of laterite soils

2.2 Classification of Laterites

Grouping the various laterites with much precision for engineering purposes with the view of classifying them has not been easy. This has resulted from the range of laterite soil types often found and the fact that the sequence of events necessary for the formation of laterite can begin in all kinds of soils. Some classification systems considered effective are:

2.2.1 The Silica to Sesquioxide Ratio

In this classification, laterite soils are grouped using silica: sesquioxide ratio (Morin et al, 1971 as referenced by Ampadu, 2007). The silica (SiO_2) content here is that remaining dissolved in the soil whereas, the sesquioxide are the amount of Fe_2O_3 and Al_2O_3, which have accumulated in the soil It is expressed as follows:

$$\frac{SiO_2}{R_2O_3} = \frac{SiO_2}{Fe_2O_3 + Al_2O_3}$$

Table 2.1 shows the relationship between the ratio and the type of laterite formed.

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Table 2.1 Silica to Sesquioxide Ratio Classification for Laterirte (Morin et al, 1971)

Silica to Sesquioxide Ratio (X)	Classification
X<1.33	True lateritites
1.33≤X≤<2.00	Lateritic soils
X>2.00	Non- lateritic soils

However, the above classification has been unpopular because it involves a chemical analysis that is not readily available to practising engineers. In addition, experience has indicated that the ratio is by no means a unique indicator of the index properties or engineering characteristics required by the engineer. Thus many other factors are of greater importance.

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2.2.2 The Chemical Weathering Index

The chemical weathering index (CWI) can be used in the classification of laterites as suggested by Sueoka, (1990) as referenced by Ampadu (2007). The chemical weathering index is defined as follows:

$$CWI = \frac{Al_2O_3 + Fe_2O_3 + TiO_2 + H_2O(\pm)\text{mole} \times 100\%}{\text{All Chemical Components}}$$

Table 2.2 below shows the relationship between CWI and the classification of laterites.

Table 2.2 Relationship between CWI and laterite classification (after Sueoka, 1900 as referenced by Ampadu, 2007)

CWI (%)	Classification
3-20	Fresh rock
20-40	Saprolite
40-60	Lateritic soil
60-90	Laterite

2.2.3 The TRL Classification System

This system classifies laterites soils into plinthite, nodular, honeycomb, hardpan and secondary laterites. In road pavement, the laterite material used is expected to be gravely in texture. For this reason usage is often made of nodular laterites. The system further defines the quartz gravel present in nodular laterite containing quartz into various classes since; their quantity tends to influence the performance of the nodular material in road pavements. Table 2.3 shows the recommended classification for this system.

Table 2.3 TRL laterite classification (after Charman, 1995 as referenced by Ampadu, 2007)

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Age	Recommended name	Characteristic
Immature (young)	Plinthite	Soil fabric containing significant amount of laterite material. Hydrated oxides present at the expense of some soil material. Unhardened, no nodules present, but there may be slight evidence of concretionary development.
	Nodular Laterite	Distinct hard concretionary nodules present as separated particles
	Honeycomb Laterite	Concretions have coalesced to form a porous structure which may be filled with some soil material
	Hardpan Laterite	Indurated laterite layer, massive and tough
Mature (old)	Secondary Laterite	May be nodular, honeycomb or hardpan, but is the result of erosion of pre-existing layer and may display brecciated appearance.

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2.3 Natural Gravels of Ghana

2.3.1 Formation

Natural gravels in the country are usually a mixture of quartz and laterite particles in a matrix of fines (Gidigasu, 1972). Depending on the predominant proportions of particles of quartz and laterite, the gravels may be quartzitic gravel (with over 80% quartz particles), lateritic gravel (with over 80% laterite particles) or lateritic-quartzitic gravels.

2.3.2 Classification

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On the basis of their physical features and mechanical characteristics, De Graft-Johnson et al. (1969) grouped natural gravels in the country into the following groups:

1. Nodular or concretionary laterites
2. Iron stone hard pans or cap rock
3. Groundwater laterites with detrital quartz
4. Colluvial and terrace laterites

The details of the characteristics of the various groups of natural gravels are presented in Table 2.4.

Table 2.4: Physical features and mechanical characteristics of laterite gravels of Ghana (De-Graft Johnson et al., 1969)

Group	Colour and Description	Specific gravity	Absorption (%)	Modified Aggregate Impact Value (%)	Aggregate Crushing Value (%)
Nodular or concretionary laterites	Dark brown	3.582	7.45	31.42	35.27
	Light brown	3.390	10.24	37.63	41.45
	Yellowish brown	3.182	13.10	46.50	51.20
Iron stone hard pans or cap rock	Dark brown (honey-comb)	2.981	16.30	41.24	38.10
	Dark brown (homogenous)	3.472	8.15	29.23	32.41
	Light-brown or reddish brown	3.041	18.42	43.60	41.67
Groundwater laterites with detrital quartz	Hard pans (Accra Plains)	3.341	11.42	34.66	32.43
	Hard pans (Forest Zone)	3.164	8.51	42.43	45.44
	Cemented clay	2.972	17.44	54.24	48.42
Colluvial and terrace laterites	Detrital irregular laterites	3.120	13.49	47.62	45.48
	Concretionary gravels cemented with clay (lower slopes)	3.260	12.65	39.62	41.61

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2.3.3 Distribution

Ghana falls mostly within the Precambrian Guinea shield of West Africa. The main Precambrian rock units existing in Ghana are the metamorphosed and folded and unfolded Birimian, Tarkwaian, Dahommeyan system, the Togo series and the Buem formation. The Birimian and the Tarkwaian rocks occur mainly in the Eastern, Central, Western Region, Ashanti, Brong Ahafo, western part of Northern and Upper regions of the country. The Dahomeyan, Togo and the Buem occur in the Volta and Eastern Regions of Ghana. It has been found out that the Precambrian rocks are overlain by late proterozoic to Paleozoic rocks of the Voltaian system which consist of sandstones, shales, mudstone, conglomerates, limestones and tillites (Kesse, 1985)

The distribution of the types of natural gravels in Ghana may be referenced to the simplified geological map of Ghana shown by Figure 2.2. Quartz gravels are found over quartzite, granite, pegmatite and other resistant rock types in the country and their general distribution is illustrated by Figure 2.3. Lateritic gravels are practically found over all rock types (igneous, sedimentary and metamorphic rocks) in the country and, therefore, have wide availability.

Generally, laterite materials over granites are often found near hills of rectangular castellated shapes, elliptically shaped, which rise gently above the level of the surroundings of the countryside (Gidigasu, 1972).

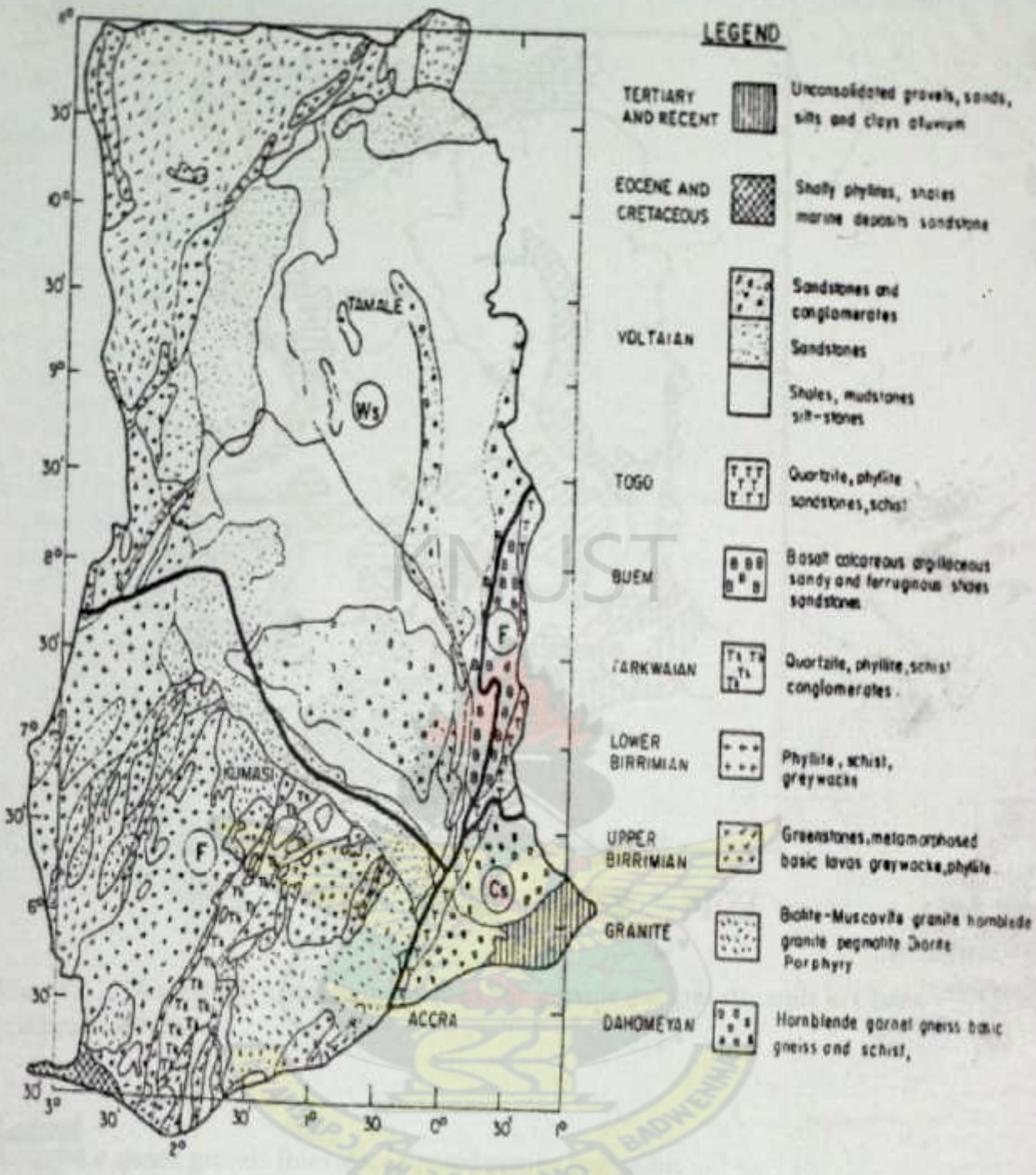

Figure 2.2: Simplified geological map of Ghana (Gidigasu, 1972)

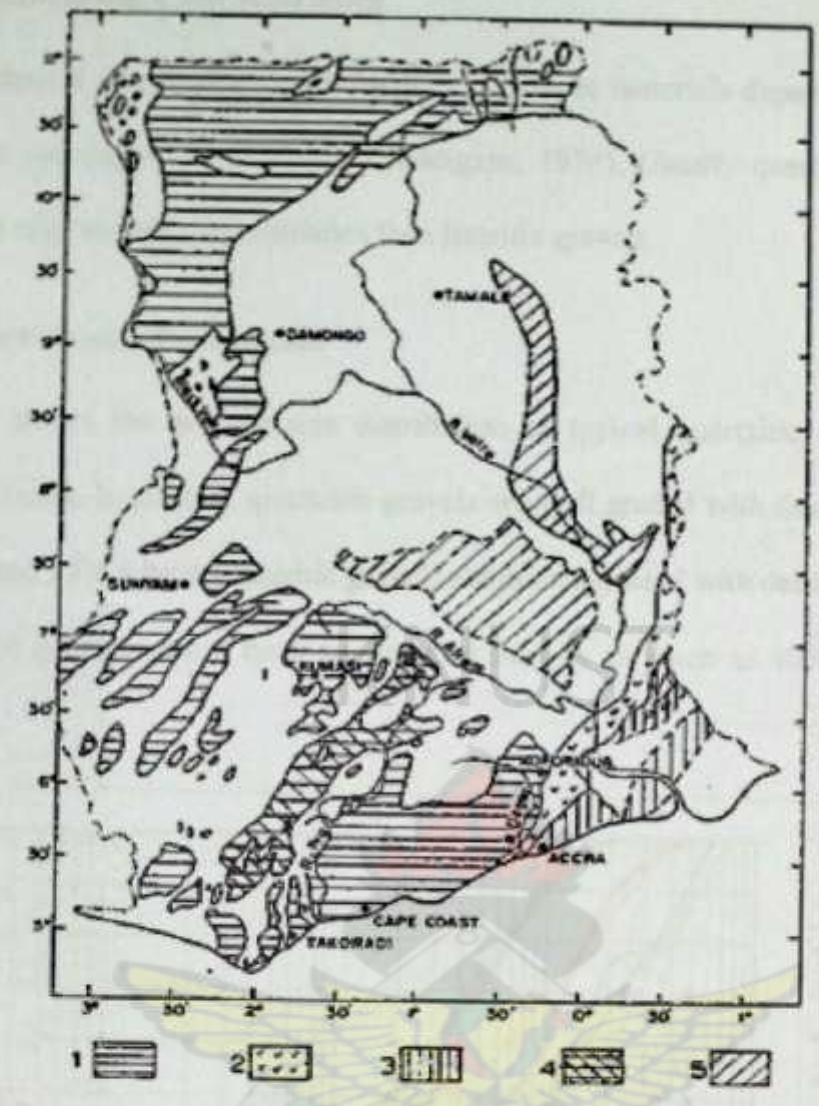

Figure 2.3: Generalised distribution of quartzitic gravels and gravelly soils in Ghana (Gidigasu, 1972).

Legend

1 - detrital quartz gravels from .decomposed granite pegmatite;

2 -weathered quartzite from Togo series;

3 - isolated outcrops of weathered quartzite and pegmatite in the Dahomeyan series;

4 - isolated outcrops of weathered quartzite in the Tarkwaian series;

5 - drift gravels in occasional pebble beds.

2.3.4 Engineering Characteristics

The geotechnical and engineering behaviour of laterite materials depend mainly on the genesis and degree of weathering (Gidigasu, 1974). Usually quartzitic gravels show better engineering characteristics than lateritic gravels.

2.3.4.1 Particle-size Distribution

Figure 2.4 shows the particle size distribution of typical quartzitic and lateritic gravels in Ghana. In general, quartzitic gravels are well graded with fines content of between 5 and 25% whereas lateritic gravels are poorly graded with deficiency in the sand fraction content, and a fines content that may be as much as 40% (Gidigasu, 1972).

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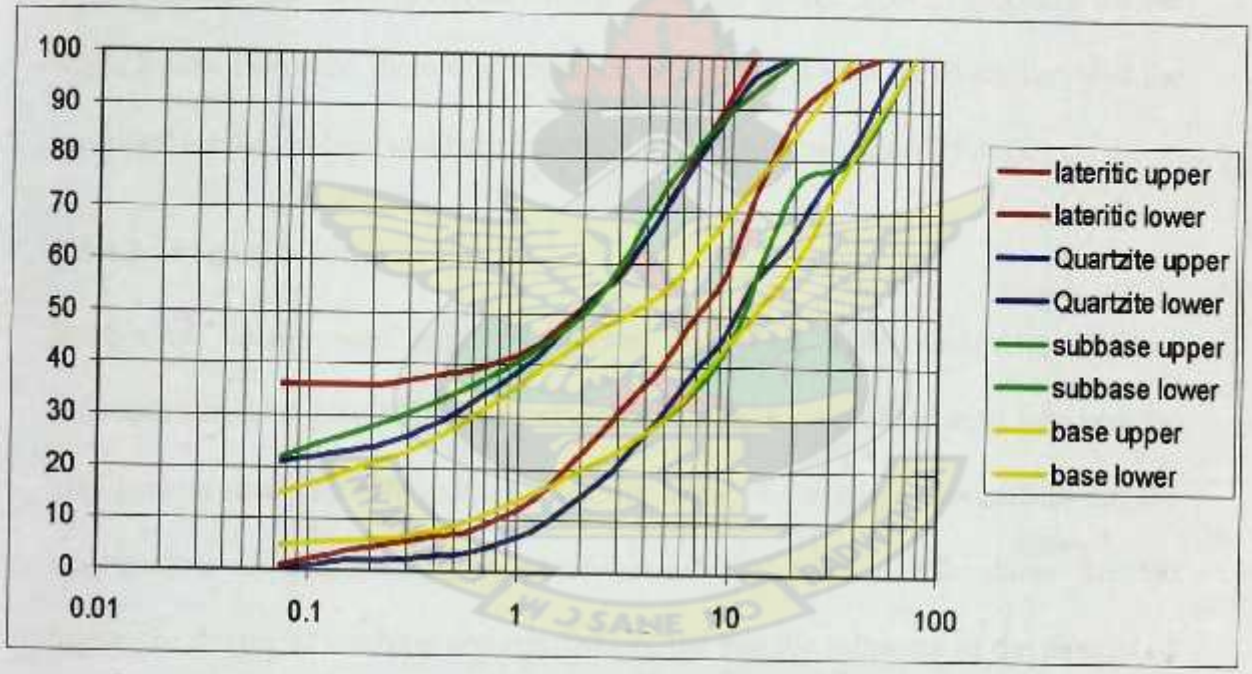

Figure 2.4: Particle-size distribution envelopes typical of concretionary laterite and quartzitic gravels identified in West Africa superimposed on MOT grading curve for sub base and base (Gidigasu, 1972)

From Figure 2.4 above it can be seen that the grading envelope for both subbase and base natural gravel material according to the Ministry of Transportation Standard specification for road and bridge works (2006) have been superimposed on the the

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envelopes typical of concretionary laterite and quartzitic gravels identified in West Africa. It is obvious from Figure 2.4 that the lower limits of the envelopes for subbase and base are within that of the concretionary laterite and quartzitic gravels for sieve sizes ranging from 0.075mm to 3mm. This is the same for the upper limits of the base and subbase envelopes but more extensive for the entire sieve sizes for the base envelope. This means that we will have more natural gravel materials meeting the grading requirement for concretionary laterite and quartzitic gravels but failing for that of base and subbase especially for the base. The assumption is confirmed from the grading envelopes drawn for subbase and base natural gravel materials where most were not meeting the grading requirement for Ministry of Transportation Standard specification for road and bridge works especially for the upper limits. However, there was not much of a problem with the lower limits of the envelope for the subbase and base materials. (Refer to Appendices H & I).

2.3.4.2 Plasticity Index

Studies on laterite soils (e.g., Dumbleton and West, 1966; Gidigasu, 1972 as referenced by Gidigasu,1976) have revealed that there is a correlation between the clay content and plasticity index for laterite soils. The average curves between the clay content and the plasticity index of a number of residual soils shows that the higher the degree of leaching and laterization, the less the influence of the amount of clay content on the plasticity index (Figure 2.5.) This may be explained in terms of the clay mineral coatings by sesquioxides, which tend to suppress the surface activity of clay minerals (Gidigasu, 1971 a; Townsend et al., 1971 as referenced by Gidigasu, 1976).

It would appear from the discussions that the plasticity index for laterite soils can be interpreted in the light of the genesis, the degree of weathering and the clay mineralogy as well as the clay size content. From the inter-relationships between the

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plasticity index on one hand and the above factor on the other hand, several geotechnical characteristics can be evaluated for residual laterite and non-laterite soils (Gidigasu, 1971, 1972 as referenced by Gidigasu, 1976), using the plasticity index.

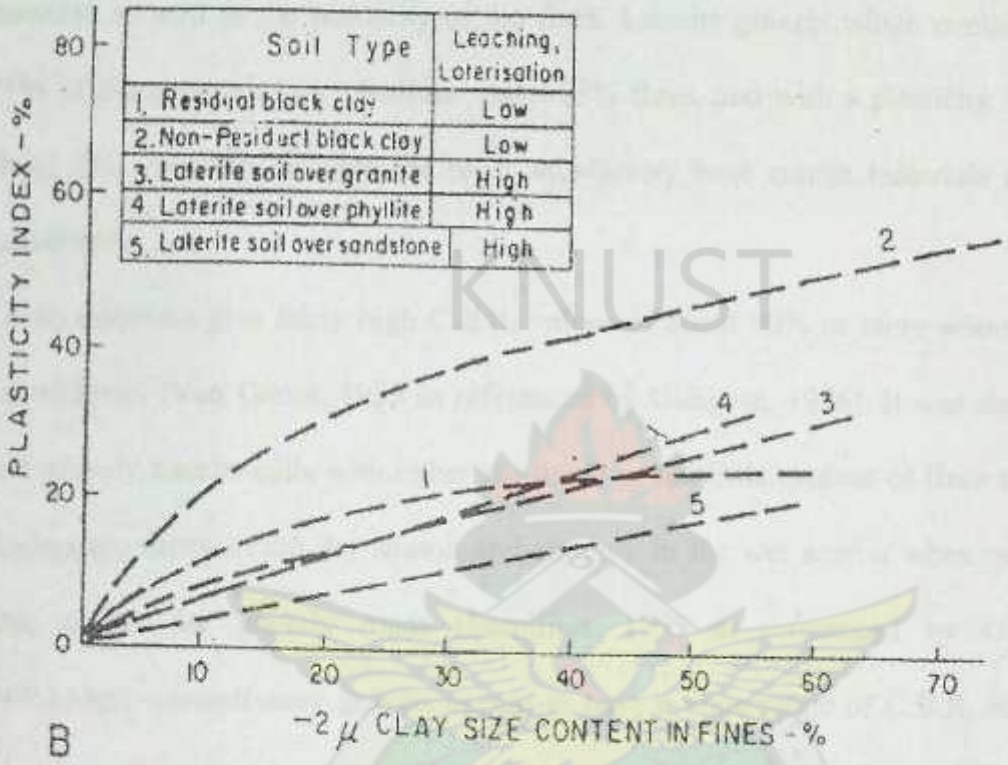

Figure 2.5: Average relation between the clay size content and plasticity index for some residual laterite soils (Gidigasu, 1972, as referenced by Gidigasu, 1976)

2.3.4.3 California Bearing Ratio (CBR)

The evaluation of C.B.R. values for laterite soils (e.g., Evans, 1958; De Graft-Johnson et al., 1968; Hammond, 1970; USAID, 1971 as referenced by Gidigasu, 1976) has shown that the stability characteristics of laterite soils may be reliably evaluated for highway and airfield-construction purposes using the C.B.R. test. Various periods of soaking the soil specimens before testing have been suggested depending on the nature of the local climate conditions. For example, under semi-

arid conditions 24-48 hour soaking periods have been found to quite adequately depict the field-moisture conditions (Ackroyd, 1959 as referenced by Gidigasu, 1976). Van Ganse (1957 as referenced by Gidigasu, 1976) found that the C.B.R. values of some compacted laterite gravels and gravely soils which were soaked for 4-days depend on the degree of compaction and mainly the content of concretionary particles as well as the plasticity of the fines. Laterite gravels which contain about 75% of the concretionary pisoliths, about 25% fines, and with a plasticity index of about 7%, generally provide the most satisfactory base course materials for road pavements.

These materials give fairly high C.B.R. values of about 80% or more when soaked for 96 hours (Van Ganse, 1957 as referenced by Gidigasu, 1976). It was also noted that gravely laterite soils with either too much or too little content of fines to act as binders are dusty in the dry season and slippery in the wet season when used as a base course for gravely roads (Remillon, 1955 as referenced by Gidigasu, 1976).Most concretionary gravels appear to have a wide range of C.B.R. values in relation to their genetic origin and particle size distribution characteristics as well as the degree of compaction and moulding moisture contents.

2.3.4.4 Aggregate Strength

The strength of lateritic gravel aggregates expressed in terms of ten percent fines value is known to increase with the sesquioxide (Fe_2O_3) content (Millard, 1962, as referenced by Gidigasu, 1972) and also increases with the age of the aggregate (Maignien, 1966, as referenced by Gidigasu, 1972). The high content of sesquioxide is manifested by high specific gravity value of the order of 2.9 to 3.5 (Table 2.4) of the gravel aggregate and depends on the parent rock and the degree of laterisation.

Bhatia and Hammond (1970) indicated that the strength of lateritic gravel aggregates is the best basis for predicting the behaviour of the material in the field. They also established that

- there is positive correlation between iron-silica oxide ratio and the strength of lateritic gravel aggregates
- laterite aggregates gain strength when subjected to heat treatment
- laterite aggregates loses strength with water absorption

A study on engineering characteristics of natural gravels in the country by de Graft-Johnson et al. (1969) indicated that a gravel material suitable for road pavement construction must have a maximum aggregate impact value of 40% for such a material to be less susceptible to weathering and mechanical degradation. Bhatia and Hammond (1970) reviewed the rating of gravels for weathering characteristics and mechanical strength as shown in Table 2.5.

Table 2.5 : Rating of gravel aggregates (Bhatia and Hammond, 1970)

Quality Rating	**Aggregate Impact Value, AIV (%)**
Excellent for road pavement	35
Good for road pavement	35-40
Average, generally unsuitable for road pavement	40-50
Very poor for road pavement	50

Quartz gravels generally show adequate strength making quartz gravels good road sub base, base and surfacing materials.

2.4 Ministry of Transportation Classification of Natural Gravel in Ghana

The Ministry of Road and Highways in the past classified natural gravel as Type 1 and Type 2 (Standard Specification for Roads and Bridges, MRH,1991-Appendix A1). Type 1 refers to natural gravel base with CBR more than 80% while Type 2 refer to natural gravel base and subbase with CBR more than 60% and 40% respectively. The standard was reviewed and now the Ministry of Transportation classifies natural gravel into 4 classes namely G80, G60, G40 and G30 in the Standard Specification for Road and Bridges (2006). The G80 and G60/G40 materials are the same as the Type 1 and Type 2 respectively. The complete specification for base and subbase relates to C.B.R., Grading, Atterberg Limits and other properties such as 10% fines is shown in Appendix A. Hence for a natural gravel material to qualify as a base it must satisfy all the criteria for G80 and G60 in relation to C.B.R., Grading, Atterberg Limits and other properties such as 10% fines as shown on Appendix A. Similarly for a subbase material, all the criteria for G40 and G30 in relation to C.B.R, Atterberg Limits and other properties such as 10% fines must also be met.

Natural gravel material must have a smooth curve within and approximately parallel to the ranges shown in Table 2.6 and Figure 2.6 as well as satisfying the minimum requirements of Table 2.7

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Table 2.6 :Grading requirement for Subbase and Base

Sieve (mm)	Percentage Passing	
	G80	G60,G40 & G30
75.0	100	100
37.5	80 - 100	80 - 100
20.0	60 - 85	75 - 100
10.0	45 - 70	45 - 90
5.0	30 - 55	30 - 75
2.00	20 - 45	20 - 50
0.425	8 - 26	8 - 33
0.075	5 - 15	5 - 22

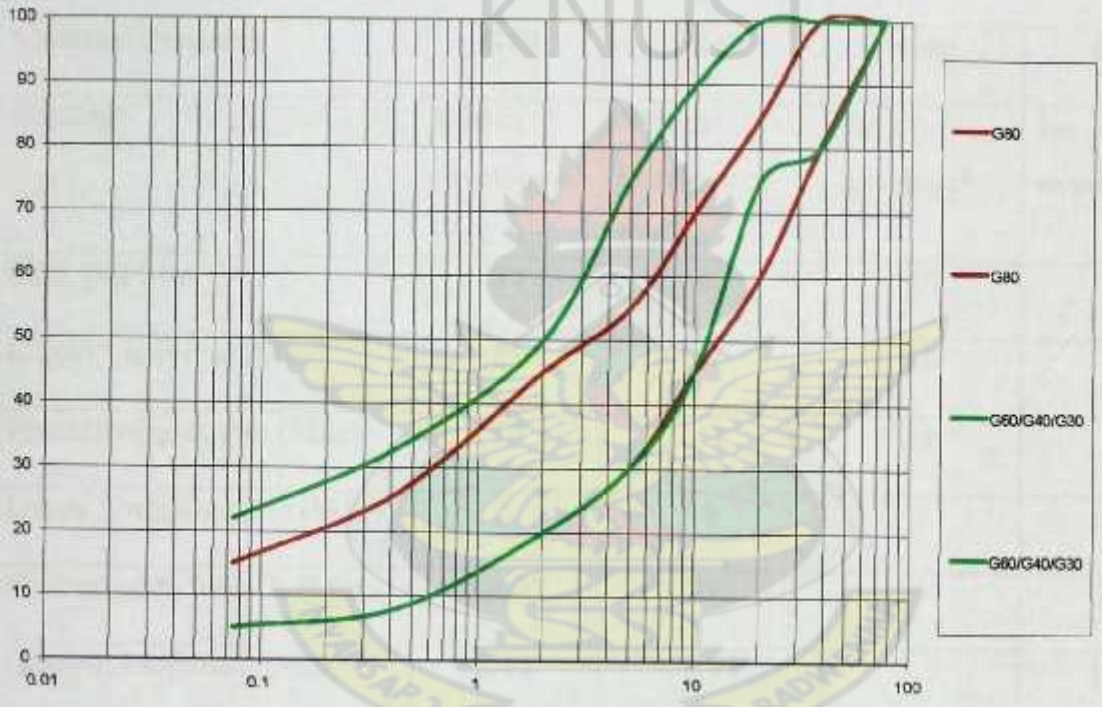

Figure 2.6: Grading envelopes for G80/G60/G40/G30 material

The classification indicates that the Atterberg limits consist of four parameters namely the liquid limit, plastic limit, linear shrinkage and plasticity modulus. The limit for each of the four parameters must be met for Atterberg limit to be satisfied (See Table 2.7). In addition California Bearing Ratio (C.B.R.) measured in percentage is also a key material property. Material classes G80 and G60 refer to natural gravel materials for bases with C.B.Rs more than 80% and 60% respectively

at an average dry density of 98% MDD (GHA S1). Similarly G40 and G30 denote minimum quality of natural gravel for subbase with C.B.Rs of 40% and 30% respectively at an average dry density of 95% MDD (GHA S1). (Standard Specification for Road and Bridge work, Table 12.2 pg 176, 2006). Table 2.7 shows the requirements for the grading, Atterberg limits, CBR and the 10% fines for subbase and base materials. The 10% fines strength determines the ability of the aggregate to withstand weathering and mechanical degradation.

Table 2.7: CBR, Grading, Atterberg Limit and 10% fines requirement for subbase and base

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Material Property	**G80**	**G60**	**G40**	**G30**
Grading	Within envelope of Fig 2.6	Within envelope of Fig 2.6	No envelope*	No envelope*
CBR (%) Min	80	60	40	30
Liquid Limit (%) (Max)	25	30	30	35
Plasticity Index (%) (Max)	10	12	14	16
Linear Shrinkage (%) (Max)	5	6	7	8
Plasticity Modulus % (Max)	200	250	250	250
Grading Modulus%(Min)	2.15	1.95	1.5	1.25
10% Fines (kN) (Min)	80	50	-	-

Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 2006, MOT, Ghana

*However the envelope of G60 was used for both G40 and G30.

2.5 Requirement of Aggregates for Otta seal

An Otta Seal (its name derives from the valley in Norway where it was used) is formed by placing graded aggregate (crushed or non-crushed, fines included) on a relatively thick film of comparatively soft binder which, on rolling and trafficking, can work its way upwards through the aggregate interstices. The characteristics of natural gravel required for Otta seal are mainly the aggregate grading, fines content, plasticity index and strength, though the key characteristics are the grading and strength (Overby, 1999).

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2.5.1 Grading

The grading or particle size distribution of the natural gravel particles should fall within and should be desirably parallel to the envelope shown in Figure 2.8. The grading requirement of aggregates for Otta seal is relaxed compared to that of aggregates for conventional chip seals and allows for a wider grading envelope. Three aggregate gradations detailed in Table 2.8 are available for construction to suit traffic conditions. The types and the associated traffic levels are as follows:

TYPE	TRAFFIC(Veh/Day)
Open	< 100
Medium	100 - 1000
Dense	> 1000

Although, the grading envelope is relatively wide, the preferred maximum size is 16mm (19mm can be tolerated for the double Otta seal). The grading of naturally occurring gravel generally falls within the specified envelope but where there is oversize material it has to be removed by screening (Overby and Pinard, 2007)

The amount of fines (particle size less than 0.075mm) in the aggregate should not exceed 10%. A higher fines content may result in constructional problems due to the finer particles being coated before the larger particles which can lead to a less durable surfacing with poor surfacing characteristics (Overby, 1999). However, in Botswana, aggregates with fines content up to 15% used for some projects have performed well and no surfacing defects attributable to the high fines content have yet been recorded (Overby, 1999).

Table 2.8: Grading requirement for Otta seal (Overby, 1999)

Sieve (mm)	**Percentage Passing**			
	Overall Grading	**Open grading (AADT<100)**	**Medium grading (100≤AADT≤1000)**	**Dense grading (AADT>1000)**
19.0	100	100	100	100
16.0	80-100	93 - 100	84 - 100	80 - 100
13.2	52-100	84 - 100	68 - 94	52 - 82
9.5	36-98	70 - 98	44 - 73	36 - 58
6.7	20-80	54 - 80	29 - 54	20 - 40
4.75	10-70	44 - 70	19 - 42	10 - 30
2.00	0-48	20 - 48	3 - 18	0 - 8
1.180	0-38	15 - 38	1 - 14	0 - 5
0.425	0-25	7 - 25	0 - 6	0 - 2
0.075	0-10	3 - 10	0 - 2	0 – 1

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Figure 2.7 is the gradation envelopes associated with open, medium and dense gradations for Otta seal superimposed on one graph.

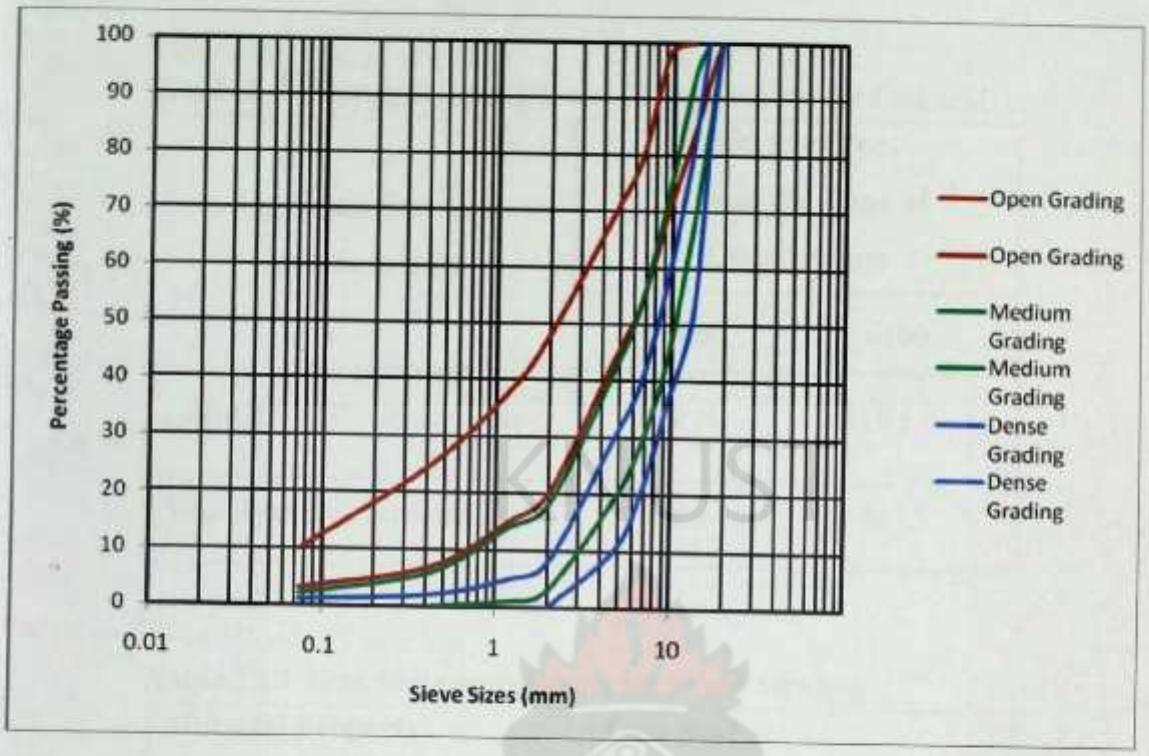

Figure 2.7: Open, medium and dense grading envelope for Otta seal (Overby and Pinard, 2007)

2.5.2 Plasticity Index

High plasticity in aggregates used for Otta seal can cause cracking and other defects and should be controlled. The recommended maximum plasticity index of fines in the aggregates for Otta seal is 10%; otherwise the fines should be removed to reduce the effect of plasticity.

2.5.3 Aggregate Strength

Aggregate strength determines the ability of the aggregate to withstand weathering and mechanical degradation which is essential for the durability of the seal. The Otta seal technology allows the use of aggregate strengths that are relatively lower than those required of conventional chip seal aggregates. The aggregate strength

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requirement detailed in Table 2.9 below depends on the level of traffic. Table 2.10 shows Otta Seal requirements for PI and gradation

Table 2.9: Aggregate strength and PI requirement for Otta seal

Aggregate Strength Requirements	**Vehicles Per Day at the Time of Construction**	
	< 100	**>100**
Min. Dry 10% Fines Value	90 k N	110 k N
Min. Wet/Dry Strength Ratio	0. 60	0. 75

Table 2.10: Otta Seal requirements for PI and Grading

Material Property	**Otta Seal**
Grading	Within envelope
PI	< 10

2.6 Logistic Regression Model

2.6.1 Selection of Model

One of the objectives of the study is to determine the probability that the selected properties meet the specification individually for subbase, base and Otta seal. This was to be done through the search for a probability function to compute that.

Logistic regression allows one to predict a discrete outcome such as group membership, from a set of variables that may be a continuous, discrete, dichotomous, or a mix of any of these. Generally, the dependent or response variable is dichotomous, such as presence/absence or success/failure. Since the outcome of

selected gravel pit meeting the specification or not is dichotomous the logistic regression is preferred. The model has been successfully used in the estimation of probability of bankruptcies of 33 firms in the United States of America. (htpp//www.irl.cornell.edu/hadi/RABE4)

The dependent or response variable in logistic regression is usually dichotomous, that is, the response variable can take the value 1 with a probability of success π , or the value 0 with probability of failure 1-π . The predictor variables can either be qualitative/quantitative or a combination of both. Therefore the probability of a gravel pit (Y) meeting the specification is dependent on the predictor variables (X) which are the material properties namely the CBR, grading, PI and LL.

2.6.2 The Logit Model

The predictor variables in logistic regression can take any form. That is, logistic makes no assumption about the distribution of the independent variables. They do not have to be normally distributed, linearly related or of equal variance within each group. The relationship between the predictor and the response variables is not a linear function in logistic regression.

Let π denote the probability that Y = 1 when X = x. The relationship between the probability π and X can often be represented by a logistic response function. It resembles an S-shaped curve, a sketch of which is given in Figure 2.8. The probability π initially increases slowly with increase in X, and then the increase accelerates, finally stabilizes, but does not increase beyond 1. The shape of the S-curve given in Fig 2.8 can be reproduced if the probabilities are modelled as follows:

$$\pi = \Pr(Y = 1 | X = x) = \frac{e^{\beta_0 + \beta_1 x}}{1 + e^{\beta_0 + \beta_1 x}}$$

where e is the base of the natural logarithm. The probabilities here are modelled by the distribution function (cumulative probability function) of the logistic distribution.

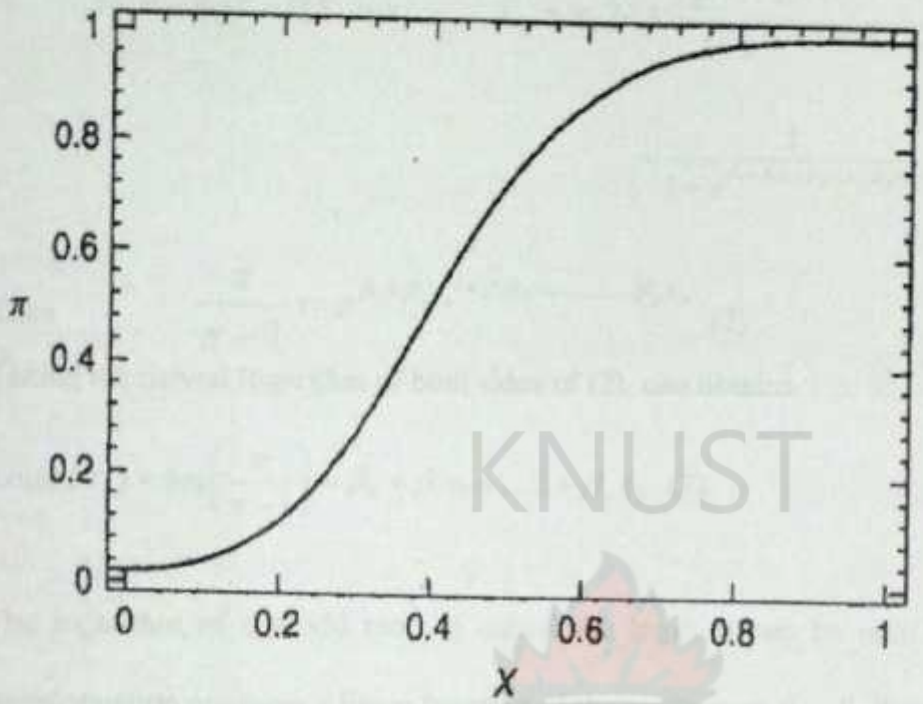

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Figure 2.8 : Logistic response function

The logistic model can be generalized directly to the situation where one has several predictor variables. The probability π is modelled as

$$\pi = \Pr\left(Y = 1 \middle| X_1 = x_1, \ldots\ldots, X_p = x_p\right)$$

$$\pi = \frac{e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots\ldots \beta_p x_p}}{1 + e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_p x_p}} \qquad (1)$$

where β_0 = constant of the equation and $\beta_1, \beta_2, \ldots\ldots\ldots \beta_p$ are the coefficients of the predictor variables. Equation (1) is the logistic regression function. It is non-linear in the parameters $\beta_0, \beta_1, \beta_2, \ldots\ldots\ldots \beta_p$. However, it can be linearized by the logit transformation. Instead of working directly with π, one works with a transformed

value of π. If π is the probability of an event happening, the equation $\pi = 1/(1-\pi)$ is called the odds ratio for the event. From equation (1)

$$1-\pi = \Pr(Y=0|X_1=x_1,.....,X_p=x_p) = 1-\frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+.....\beta_p x_p}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+...\beta_p x_p}}$$

$$= \frac{1}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+...\beta_p x_p}}$$

Then $$\frac{\pi}{\pi-1} = e^{\beta_0+\beta_1 x_1+\beta_2 x_2+.....\beta_p x_p} \quad (2)$$

Taking the natural logarithm of both sides of (2), one obtains

$$\text{Logit}(\pi) = \log\left(\frac{\pi}{\pi-1}\right) = \beta_0+\beta_1 x_1+.....+\beta_p x_p \quad (3)$$

The logarithm of the odd ratio is called the logit. It can be seen that the logit transformation produces a linear function of the parameters β_0, $\beta_1, \beta_2, ...\beta_p$.

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CHAPTER THREE

3 METHODOLOGY

3.1 Data Collection

Data on gravel materials were collected from the three road agencies namely, the Department of Feeder Roads (DFR), Department of Urban Roads (DUR) and Ghana Highway Authority (GHA) under the Ministry of Transportation.

The procedure for the data collection is outlined:

(1) In order to plan the data collection, discussions were held with the head of the Planning Division of the Ghana Highway Authority to understand how such data is stored. The discussion showed that it appeared donor-funded projects had more complete data collection on material investigation.

(2) A list of donor-funded projects was then compiled.

(3) From the list, road projects were chosen such that they were representative of the whole country.

(4) Material investigation reports of these selected road projects produced by Consultants during project feasibility studies were assembled.

(5) The data was in hard copy format and as such photocopies of all the reports were obtained. The feasibility studies reports covered a period of 10 years from 1997 to 2007.

3.2 Data Entry

The various reports were assembled and studied. A spreadsheet in Excel was made after which the information in the reports was transferred onto the spreadsheet by typing. Information extracted from the material investigation reports were percentage passing for each sieve size, the liquid limit, plastic limit and plasticity index for each

borrow pit location. The data inputted was cross checked with the original to correct any mistakes made. The grading values for each sample were plotted on the grading band.

3.3 Analysis of Data

Two approaches were used for the analysis namely – the Manual Method and the Logit Method.

The Manual Method

In the first approach each parameter value was individually compared with the threshold in the specification and decision made to whether it passed (P) or failed (F). When there is insufficient data to decide it is classified as Non-classified (NC). This was manually done for each parameter. Also the results of the individual parameters were compared and a decision taken for each sample. A sample was indicated as to have passed (P) when all the parameters indicate "P". A failure in one parameter revealed the sample failed.

Logit Method

Each material property was then compared with the MoT specification for material classes G30, G40, G60 and G80 respectively. The grading values (X_1) for each sample were plotted on the grading band. The curves falling within the envelope were determined as "passed" (X_1=1) while those outside the envelope were classified as "failed" (X_1=0). A similar thing was done for the remaining parameters by assigning those meeting the requirement as passed or otherwise as failed. The number that did not have sufficient information to allow a decision of passing or failing to be made was shown as non-classified. The table below shows a typical spread sheet.

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Table 3.1: Typical spread sheet

Parameter	Logit (Y)	Manual
	0 for failure 1 for pass	P= Pass F=Failure NC=Non-Classified
Grading (X_1)		
Liquid Limit (X_2)		
Plastic Limit (X_3)		
Soaked CBR (X_4)		

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The results were tabulated according to the number of samples received from the various road agencies. Since the country is divided into ten (10) regions, the results were also tabulated on a regional basis in terms of gradation, grading modulus, CBR and Atterberg Limits. The analysis was performed at four (4) different levels namely:

(1) Parameter level

(2) Sample level

(3) Regional level

(4) National level

3.4 Locations of Gravel Samples

With the aid of a district map of Ghana the approximate locations of the gravel samples investigated were located as shown in Figure 3.1. The details on some of the districts of the gravel locations and the roads along which the borrow pits were identified are provided in Tables B1 to B10 in Appendix B. Information on some borrow pits were scanty so they could not be located on the map

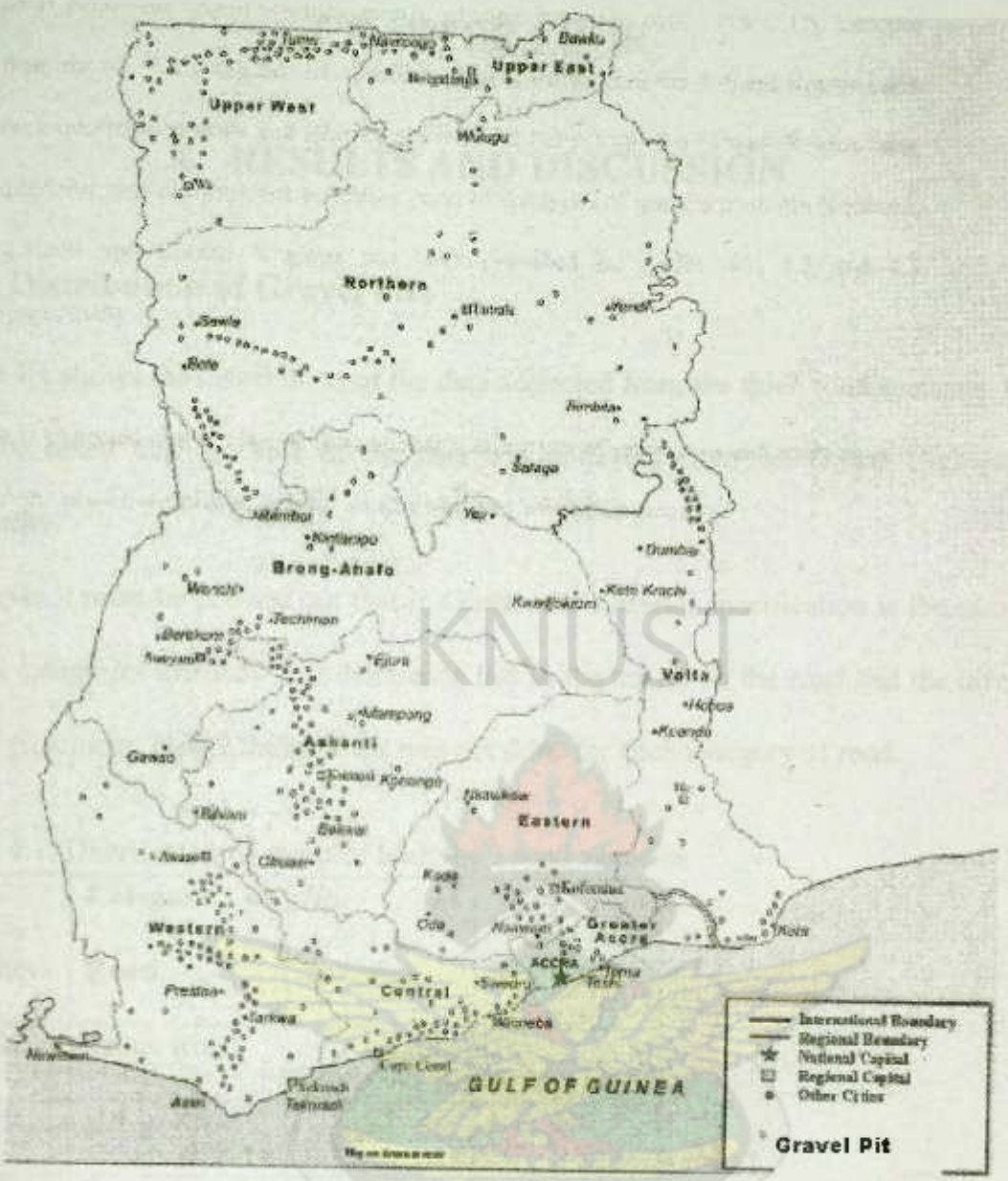

Figure 3.1: Locations of gravel samples

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CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Distribution of Gravel Pits

Table 4.1 shows the distribution of the data collected from the three road agencies. It may be noted that the bulk of the data was collected from the Ghana Highway Authority.

However it must be pointed out that in Ghana, the material specification is the same for all categories of roads. The difference lies in the traffic on the road and the layer of the pavement. Hence the analysis was not done for each category of road.

Table 4.1: Distribution of samples from the 3 road agencies

Agency	Category of Road	No. of Samples	% of Sample
GHA	Trunk Road	361	79
DUR	Urban Road	22	5
DFR	Feeder Road	71	16
Total		**454**	**100**

The regional distribution of the data is shown in Table 4.2. The smallest number of data was obtained from the Upper East Region while the Ashanti Region gave the highest number of 75.

Table 4.2: Regional Distribution of number of secondary data

Region	No. of Samples	% of Sample
Northern Region	68	15
Upper West Region	57	12
Upper East Region	19	4
Ashanti Region	75	17
Western Region	72	16
Brong Ahafo Region	23	5
Eastern Region	24	5
Central Region	56	12
Volta Region	39	9
Greater Accra	21	5
Total	**454**	**100**

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4.2 Natural Gravel Subbase Material

4.2.1 Specification

According to MoT specification, natural gravel material is said to have passed the requirement for subbase if the criteria shown in Table 4.3 have been met. The G40 specification is for subbase material of CBR ≥ 40% while the G30 is also for a subbase material with CBR ≥ 30.

Table 4.3:MoT requirements for subbase material

Material Property	G40	G30
Grading	No envelope	No envelope
Plastic Limit (%)	≤ 14	≤ 16
Liquid Limit (%)	≤ 30	≤ 35
CBR (%)	≥ 40	≥ 30
Grading Modulus	≥ 1.5	≥ 1.25
Linear Shrinkage	≤ 7	≤ 8
Plasticity Modulus	≤ 250	≤ 250
CBR Swell	≥ 0.5	≥ 1.0

Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 2006, MOT, Ghana

The specification is silent on grading for G40 and G30. However in this study, the grading envelope for G60 as shown in Figure 2.6 was used for both G30 and G40. This envelope is the same as the one used in the previous MRH specification (1991) for the gradation of subbase materials (Compare Appendix A1 and A2). G40 is a material of slightly higher quality than the G30. In this study a gravel pit is said to have passed the specification of a subbase material if it satisfies the requirements of grading, plasticity index, liquid limit and CBR.

4.2.2 Individual Parameters

Table 4.4 shows the number of samples satisfying individually each of the four parameters. A similar comparison for G30 is also shown in Table 4.5.

Table 4.4: Number Gravel pits passing or failing various requirements of G40 specification

Region	No. Of samples	Grading			PI			LL			CBR		
		P	F	NC	P	F	NC	P	F	NC	P	F	NC
NR	68	43	20	5	59	9	0	47	2	19	29	10	29
UWR	57	46	11	0	54	3	0	36	5	16	36	5	16
UER	19	5	12	2	11	3	5	4	0	15	2	2	15
AR	75	41	25	9	36	31	8	33	34	8	49	9	17
WR	72	23	49	0	50	22	0	14	39	19	36	17	19
BAR	23	5	15	3	15	8	0	4	3	16	5	1	17
ER	24	10	14	0	10	8	6	9	5	10	9	3	12
CR	56	38	18	0	33	21	2	13	27	16	15	13	28
VR	39	23	16	0	29	10	0	20	8	11	28	0	11
GAR	21	12	9	0	16	0	5	15	1	5	5	1	15
Total	454	246	189	19	313	115	26	195	124	135	214	61	179

P = Pass F = Fail NC = Non classified

In the tables, for each material property, the number passing the specification (P) and failing the specification (F) is shown. The number of samples that did not contain sufficient information to allow a decision is also shown as NC.

Table 4.5: Number Gravel pits passing or failing various requirements of G30 specification

Region	No. Of samples	Grading			PI			LL			CBR		
		P	F	NC	P	F	NC	P	F	NC	P	F	NC
NR	68	43	20	5	62	6	0	48	1	19	36	3	29
UWR	57	46	11	0	57	0	0	41	0	16	38	3	16
UER	19	5	12	2	12	2	5	4	0	15	3	1	15
AR	75	41	25	9	42	25	8	42	25	8	56	2	17
WR	72	23	49	0	62	10	0	28	25	19	45	8	19
BAR	23	5	15	3	18	5	0	6	1	16	6	0	17
ER	24	10	14	0	11	7	6	10	4	10	10	2	12
CR	56	38	18	0	38	16	2	24	16	16	18	10	28
VR	39	23	16	0	33	6	0	22	6	11	28	0	11
GAR	21	12	9	0	16	0	5	16	0	5	5	1	15
Total	454	246	189	19	351	77	26	241	78	135	245	30	179

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Table 4.6: Availability of Material Meeting G-40 Specification

Region	No. of samples	Grading				PI				LL				CBR			
		P	F	Total	% P	P	F	Total	% P	P	F	Total	% P	P	F	Total	% P
NR	68	43	20	63	68%	59	9	68	87%	47	2	49	96%	29	10	39	74%
UWR	57	46	11	57	81%	54	3	57	95%	36	5	41	88%	36	5	41	88%
UER	19	5	12	17	29%	11	3	14	79%	4	0	4	100%	2	2	4	50%
AR	75	41	25	66	62%	36	31	67	54%	33	34	67	49%	49	9	58	84%
WR	72	23	49	72	32%	50	22	72	69%	14	39	53	26%	36	17	53	68%
BAR	23	5	15	20	25%	15	8	23	65%	4	3	7	57%	5	1	6	83%
ER	24	10	14	24	42%	10	8	18	56%	9	5	14	64%	9	3	12	75%
CR	56	38	18	56	68%	33	21	54	61%	13	27	40	33%	15	13	28	54%
VR	39	23	16	39	59%	29	10	39	74%	20	8	28	71%	28	0	28	100%
GAR	21	12	9	21	57%	16	0	16	100%	15	1	16	94%	5	1	6	83%
Total	454	246	189	189	57%	313	115	428	73%	195	124	319	61%	214	61	275	78%

Table 4.7: Availability of Material Meeting G-30 Specification

Region	No. of samples	Grading				PI				LL				CBR			
		P	F	Total	% P	P	F	Total	% P	P	F	Total	% P	P	F	Total	% P
NR	68	43	20	63	68%	62	6	68	91%	48	1	49	98%	36	3	39	92%
UWR	57	46	11	57	81%	57	0	57	100%	41	0	41	100%	38	3	41	93%
UER	19	5	12	17	29%	12	2	14	86%	4	0	4	100%	3	1	4	75%
AR	75	41	25	66	62%	42	25	67	63%	42	25	67	63%	56	2	58	97%
WR	72	23	49	72	32%	62	10	72	86%	28	25	53	53%	45	8	53	85%
BAR	23	5	15	20	25%	18	5	23	78%	6	1	7	86%	6	0	6	100%
ER	24	10	14	24	42%	11	7	18	61%	10	4	14	71%	10	2	12	83%
CR	56	38	18	56	68%	38	16	54	70%	24	16	40	60%	18	10	28	64%
VR	39	23	16	39	59%	33	6	39	85%	22	6	28	79%	28	0	28	100%
GAR	21	12	9	21	57%	16	0	16	100%	16	0	16	100%	5	1	6	83%
Total	454	246	189	189	57%	313	115	189	82%	246	189	189	81%	214	61	275	87%

From Table 4.6 whereas 73%, 61% and 78% respectively met the PI, LL and CBR requirements only 57% met the grading requirement for G40. But when taken together overall, UER, WR and BAR gave low percentages of material meeting grading requirements. WR and CR appear to have the greatest difficulty of meeting LL requirements representing 26% and 33% respectively. Most data met the PI and CBR requirements, though.

For G30 material, 82%, 81% and 87% of material nationwide met PI, LL and CBR requirements. Since the same grading was used for both G40 and G30, there was no deviation for gradation and hence will be the same as already discussed under G40.

From Tables 4.6and 4.7 the number of gravel pit meeting the requirements for PI and LL in WR increased significantly from 69% and 26% to 86% and 53% respectively. The difficulty of finding gravel pit meeting LL improved from 49% and 33% to 63% and 60% respectively when G30 subbase material is used for AR and CR. In general the number of gravel pits meeting LL requirements when G30 subbase material instead of G40 increased from 61% to 81%.

4.2.3 All Parameters

The number of gravel deposits meeting the specification for the four material properties has been summarized in Tables 4.8 and 4.9 for G40 and G30 respectively. The tables show the regional distribution of the various percentages of samples passing. It can be seen that the percentage passing varies between 5-57 % for G40 and 5-69 % for G30. The total number of natural gravel deposits that met the requirements for subbase increased from 94 to 114 when G30 materials are used as subbase. There was not much change in the number of gravel pits meeting the specification as the same grading used for both G40 and G30 appears to suggest that

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grading plays a very important role in deciding whether a material meets specification or not.

NR and UWR have the highest percentages passing as a G40 subbase material and VR being just okay. It is however surprising to observe the UER is among the regions having the lowest numbers meeting specification because it has the same geological formation and rainfall pattern as NR and UWR. This could perhaps have been due to the sample size of materials not being enough for statistical analysis.

The overall national increase is from 26% to 32% when G30 subbase material is used instead of G40.

Table 4.8Regional Distribution of number of natural gravel pits passing or failing the requirements of G40 specification

NR	23	31	54	43%
UWR	24	18	42	57%
UER	1	14	15	7%
AR	16	52	68	24%
WR	3	56	59	5%
BAR	1	16	17	6%
ER	1	20	21	4%
CR	9	33	42	21%
VR	12	23	35	34%
GAR	4	10	14	29%
Total	**94**	**273**	**367**	**26%**

Table 4.9: Regional Distribution of number of natural gravel pits passing or failing the requirements of G30 specification

Region	ALL PARAMETERS FOR G30			
	Passed	Failed	Total	% P
NR	27	27	54	50%
UWR	29	13	42	69%
UER	1	13	14	7%
AR	21	44	65	32%
WR	5	53	58	9%
BAR	2	15	17	12%
ER	1	20	21	5%
CR	10	28	38	26%
VR	14	21	35	40%
GAR	4	10	14	29%
Total	**114**	**244**	**358**	**32%**

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4.3 Natural Gravel Base Material

4.3.1 Specification

According to MoT specification, a natural gravel material is said to have met the requirement for base if the criteria shown in Table 4.8 are satisfied. G80 specification is materials which have CBR $\geq$ 80 and are used as base course for high traffic roads while G60 is material having a CBR$\geq$ 60 and are used as base course for low traffic roads. G40 specification can also serve as a base course for sealed rural access roads with its material properties being the same as the subbase.

Table 4.10 :MoT requirements for Base Material

Material Property	**G80**	**G60**	**G40**
Grading	Within envelope	Within envelope	No envelope
Plastic Limit (%)	≤ 10	≤ 12	≤ 14
Liquid Limit (%)	≤ 25	≤ 30	≤ 30
CBR(%)	≥ 80	≥ 60	≥ 40
Grading Modulus	≥ 2.15	≥ 1.95	≥ 1.5
Linear Shrinkage	≤ 5	≤ 6	≤ 7
Plasticity Modulus	≤ 200	≤ 250	≤ 250
CBR Swell	≥ 0.25	≥ 0.5	≥ 0.5
10% Fines(KN)	≥ 80	≥ 50	–

Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 2006,MOT, Ghana

The grading for natural gravel base material must have a smooth curve within and appropriately parallel to the envelope already shown in Figure 2.6 for G80 and G60 respectively. There is, however, no gradation for G40. G80 is also a material of slightly higher quality than the G60. G40 is used as a base material for rural access roads.

In this study a gravel deposit is said to have met the specification of a base material if it satisfies the requirement of grading, liquid limit, plasticity index and CBR.

4.3.2 Individual Parameters

Tables 4.11 and 4.12 show the number of samples satisfying individually each of the four parameters for G80 and G60 respectively.

Table 4.11: Number of Gravel pits passing or failing various requirements for G80 specifications

Region	No. Of samples	Grading			PI			LL			CBR		
		P	F	NC	P	F	NC	P	F	NC	P	F	NC
NR	68	8	55	5	47	21	0	43	6	19	11	28	29
UWR	57	7	50	0	48	9	0	27	14	16	4	37	16
UER	19	2	15	2	9	5	5	4	0	15	1	3	15
AR	75	3	63	9	18	49	8	23	44	8	21	37	17
WR	72	7	65	0	21	51	0	6	47	19	10	43	19
BAR	23	0	20	3	14	9	0	4	3	16	1	5	17
ER	24	2	22	0	5	13	6	7	7	10	4	8	12
CR	56	4	52	0	13	41	2	9	31	16	7	21	28
VR	39	4	35	0	28	11	0	16	12	11	11	17	11
GAR	21	2	19	0	9	7	5	15	1	5	1	5	15
Total	454	39	396	19	212	216	26	154	165	135	71	204	179

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Table 4.12: Number of Gravel pits passing or failing various requirements for G60 specifications

Region	No. Of samples	Grading			PI			LL			CBR		
		P	F	NC	P	F	NC	P	F	NC	P	F	NC
NR	68	43	20	5	52	16	0	47	2	19	19	20	29
UWR	57	46	11	0	49	8	0	36	5	16	17	24	16
UER	19	5	12	2	11	3	5	4	0	15	2	2	15
AR	75	41	25	9	34	33	8	33	34	8	34	24	17
WR	72	23	49	0	30	42	0	14	39	19	17	36	19
BAR	23	5	15	3	15	8	0	4	3	16	3	3	17
ER	24	10	14	0	9	9	6	9	5	10	6	6	12
CR	56	38	18	0	19	35	2	13	27	16	9	19	28
VR	39	23	16	0	29	10	0	20	8	11	17	11	11
GAR	21	12	9	0	12	4	5	15	1	5	2	4	15
Total	454	246	189	19	260	168	26	195	124	135	126	149	179

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Table 4.13: Availability of Material Meeting G-80 Specification

Region	No. of samples	Grading				PI				LL				CBR			
		P	F	Total	% P	P	F	Total	% P	P	F	Total	% P	P	F	Total	% P
NR	68	8	55	63	13%	47	21	68	69%	43	6	49	88%	11	28	39	28%
UWR	57	7	50	57	12%	48	9	57	84%	27	14	41	66%	4	37	41	10%
UER	19	2	15	17	12%	9	5	14	64%	4	0	4	100%	1	3	4	25%
AR	75	3	63	66	5%	18	49	67	27%	23	44	67	34%	21	37	58	36%
WR	72	7	65	72	10%	21	51	72	29%	6	47	53	11%	10	43	53	19%
BAR	23	0	20	20	0%	14	9	23	61%	4	3	7	57%	1	5	6	17%
ER	24	2	22	24	8%	5	13	18	28%	7	7	14	50%	4	8	12	33%
CR	56	4	52	56	7%	13	41	54	24%	9	31	40	23%	7	21	28	25%
VR	39	4	35	39	10%	28	11	39	72%	16	12	28	57%	11	17	28	39%
GAR	21	2	19	21	10%	9	7	16	56%	15	1	16	94%	5	1	6	17%
Total	454	39	396	435	9%	212	216	428	51%	154	165	319	58%	71	204	275	26%

Table 4.14: Availability of Material Meeting G-60 Specification

Region	No. of samples	Grading				PI				LL				CBR			
		P	F	Total	% P	P	F	Total	% P	P	F	Total	% P	P	F	Total	% P
NR	68	43	20	63	68%	52	16	68	76%	47	2	49	96%	19	20	39	49%
UWR	57	46	11	57	81%	49	8	57	86%	36	5	41	88%	17	27	41	41%
UER	19	5	12	17	29%	11	3	14	79%	4	0	4	100%	2	2	4	50%
AR	75	41	25	66	62%	34	33	67	51%	33	34	67	49%	34	24	58	59%
WR	72	23	49	72	32%	30	42	72	42%	14	39	53	26%	17	36	53	32%
BAR	23	5	15	20	25%	15	8	23	65%	4	3	7	57%	3	3	6	50%
ER	24	10	14	24	42%	9	9	18	50%	9	5	14	64%	6	6	12	50%
CR	56	38	18	56	68%	19	35	54	35%	13	27	40	33%	9	19	28	32%
VR	39	23	16	39	59%	29	10	39	74%	20	8	28	71%	17	11	28	61%
GAR	21	12	6	21	57%	12	4	16	75%	15	1	16	94%	2	4	6	33%
Total	454	246	396	435	57%	260	168	428	61%	154	165	319	61%	126	149	275	46%

From Table 4.13 it can be observed that materials from AR, WR and CR had the greatest difficulty of meeting PI and LL requirements for G80 base material. Whereas 51%, 58% and 26% respectively met the PI, LL and CBR requirements only 9% met the grading requirement for G80. All gravel deposits seems to have difficulty meeting the requirements for grading and CBR. Materials from AR, WR, ER and CR appear to have great difficulty meeting the PI and LL requirements.

A quick review of the data in Table 4.14 shows for example that WR and CR had the greatest difficulty meeting LL and PI requirements. Materials from WR, CR and GAR appear to have the greatest difficulty meeting CBR requirements.

A comparison of data in Tables 4.13 and 4.14 shows that gravel pits meeting the grading requirements for G80 increased from 9% to 57% when G60 grading requirement was used. This means that grading plays a very important part in deciding whether a natural gravel material meets specification or not. In addition, the number of gravel pits meeting CBR requirements increased from 26% to 46% respectively for G80 and G60.

4.3.3 All Parameters

The number of samples for all four material properties meeting the specification has been summarized in Tables 4.15 and 4.16. The tables show the regional distribution of the various percentages of samples G80 and G60 specification respectively.

Table 4.15: Regional Distribution of number of gravel pit passing or failing the requirements of G80 specification

Region	ALL PARAMETERS FOR G80			
	Passed	Failed	Total	% P
NR	5	63	68	7%
UWR	1	54	55	2%
UER	1	17	18	6%
AR	0	71	71	0%
WR	0	71	71	0%
BAR	0	22	22	0%
ER	0	24	24	0%
CR	0	56	56	0%
VR	0	35	35	0%
GAR	0	19	19	0%
Total	**7**	**432**	**439**	**2%**

Table 4.16: Regional Distribution of number of gravel pit passing or failing the requirements of G60 specification

Region	ALL PARAMETERS FOR G60			
	Passed	Failed	Total	% P
NR	15	47	62	24%
UWR	10	33	43	23%
UER	1	14	15	7%
AR	12	59	71	17%
WR	0	61	61	0%
BAR	1	18	19	5%
ER	1	20	21	5%
CR	5	39	44	11%
VR	11	24	35	31%
GAR	2	11	13	15%
Total	**114**	**244**	**358**	**15%**

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From Tables 4.15 and 4.16, it can be observed that the percentage of natural gravel samples that met the requirements in the various regions for G80 varies between 0-7% and that of G60 is between 0-31%. The overall national percentages of natural gravel meeting the requirement for G80 and G60 are 2 and 15% respectively. Apart from NR, UWR and UER where 7%, 2% and 6% respectively met the requirements for G80 all the materials failed to meet the specification.

The result appears to indicate that grading and CBR are key factors influencing the probability of a natural gravel material meeting the specification for G80 base.

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Figures 4.1 to 4.4 show the percentages of gravel locations meeting G80, G60, G40 and G30 requirements respectively.

Figure 4.1: Percentages of gravel pits meeting the MoT requirement for G80

Figure 4.2: Percentages of gravel pits meeting the MoT requirement for G60

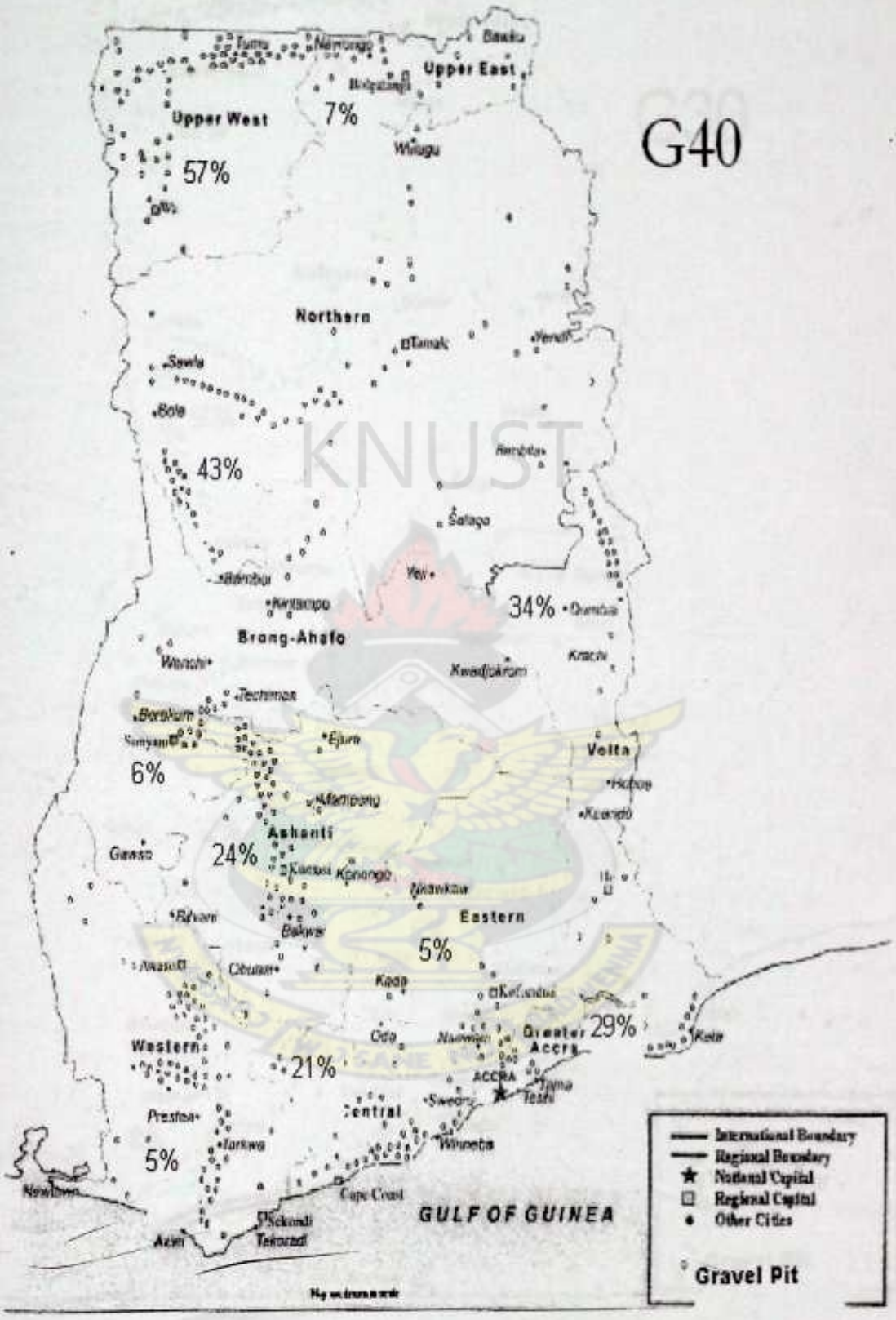

Figure 4.3: Percentages of gravel pits meeting the MoT requirement for G40

Figure 4.4: Percentages of gravel pits meeting the MoT requirement for G30

4.4 Natural Gravel Material Meeting Requirement for Otta seal

4.4.1 Specification

The specification for Otta seal are grading, plasticity index and aggregate strength measured in terms of 10% fines value. The minimum requirement for Otta seal surfacing is shown in Table 4.17 below.

Table 4.17: Requirements for Otta Seal

Material Property	**Otta Seal**
Grading	Within envelope
PI	< 10 %
Min. Dry 10% Fines Value	>90 KN
Min. Wet/Dry Strength Ratio	>0.60

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In this study only grading and PI were used in the determination of the suitability of natural gravel for Otta seal.

4.4.2 Individual Parameters

Table 4.18 shows the number of samples satisfying individually each of the two parameters namely grading and PI.

The grading curves of practically all the 454 natural gravel samples deviated from the Otta seal grading envelop (See Appendix J) and showed coarse particle sizes above 19mm (See Appendix E)

Table 4.18: Availability of Material meeting Otta Seal Specification

Region	No. Of samples	Grading				PI				% Sample Passing
		P	F	Total	%P	P	F	Total	%P	
NR	68	1	62	63	2%	47	21	68	69%	0%
UWR	57	0	57	57	0%	48	9	57	84%	0%
UER	19	0	17	17	0%	9	5	14	64%	0%
AR	75	0	66	66	0%	18	49	67	27%	0%
WR	72	0	72	72	0%	21	51	72	29%	0%
BAR	23	0	20	20	0%	14	9	23	61%	0%
ER	24	0	24	24	0%	5	13	18	28%	0%
CR	56	0	56	56	0%	13	41	54	24%	0%
VR	39	0	39	39	0%	28	11	39	72%	0%
GAR	21	0	21	21	0%	9	7	16	56%	0%
Total	454	1	434	435	0%	212	216	428	50%	0%

With the exception of NR where 2% met the grading specification, none of the material for the other regions met the grading specification for Otta seal. In contrast to grading, 50% of the material overall met the PI requirement. The data in Table 4.18 shows that for example that AR, WR, ER and CR had the greatest difficulty meeting PI specification.

In fact UWR and VR had as high as 84% and 61% respectively meeting the PI requirement. Thus the main problem with the material meeting Otta seal specification arises because of grading. This is the reason why screening the particles

Table 4.19 shows the percentage that passed for Otta seal gradation after one or two cycles of processing.

Table 4.19: Samples passing after processing

Processing Cycle	% Passing
0	0
1	78
2	100

Source Braimah(2006)

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By inference all the gravel pits will meet Otta seal requirements for grading when subjected to two or more cycles of processing.

4.5 Probabilities

The analysis of the probabilities was to be done using the logistic regression model. The response variable (Y) that is the probability that a sample meets the specification takes values of 1 for pass or 0 for failure. The predictor variables (X) in this instance are X_1= grading, X_2=LL, X_3=PI and X_4=CBR.

For a gravel pit to meet the requirement of LL, PI and CBR conditions were set in the model as follows:

X_1= Grading X_1 [1,0]

X_2=LL X_2=1 if $x < 25$

X_2=0 if $x \geq 25$

X_3=PI X_3=1 if $x < 10$

X_3=0 if $x \geq 10$

X_4=CBR X_4=1 if $x \geq 80$

X_4=0 if $x < 80$

The individual values for CBR, PI and LL are used for the model. Since grading is qualitative values of 1 and 0 were assigned to passed and failed respectively.

For example to find the probability that a gravel sample in the Northern region will meet the specification for G80 base the values in Table 4.20 are inputted into the model.

Table 4.20: Results of all 4 parameters of natural gravel in the NR compared to G80 base specification (From Appendix D1)

Y	x_1(grading)	x_2 (LL)	x_3(PI)	x_4(CBR)
0	0	17.2	4.9	85
0	0	17.8	5.5	75
0	0	14.8	4.7	56
0	0	17.8	7.2	80
0	0	17.4	4.6	42
0	0	17.4	4.7	45
0	0	18.2	5.7	55
0	0	17	3.5	32
0	0	0	0	35
0	1	26.6	8.6	55
0	0	21.2	6.5	50
0	1	24.6	5.8	51
0	0	22.2	5	65
0	0	21.8	6.9	23
0	0	23.8	5.6	20
0	0	19.8	6	33
0	0	19.4	5.5	46
0	0	17.8	4.4	60
1	1	19	5	95
0	0	18	5	69
0	0	57	31	50
0	0	19	6	90
0	0	0	0	50
0	0	0	0	50
0	0	0	0	118
0	0	0	0	125
0	0	0	0	200
0	0	0	0	32
0	0	0	0	44
1	1	0	0	93
1	1	0	0	102
1	1	0	0	93
0	1	0	0	60
1	1	0	0	97

Logistic Regression Model

The logistic response function is given by

$$\pi = \Pr\left(Y = 1 | X_1 = x_1, \ldots\ldots, X_p = x_p\right)$$

$$\pi = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\ldots\ldots\beta_p x_p}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\ldots\beta_p x_p}} \quad (1)$$

where β_0 is a constant and $\beta_1, \beta_2, \ldots\ldots\ldots\beta_p$ are the coefficients of the responsive variables .

The output from the model is as shown below:

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Variables in the Equation

Table 4.21: Output from the logistic Regression Model using X1, X2, X3 and X4.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	x1	134.029	11816.858	.000	1	.991	1.615E+058
	x2	-5.862	840.789	.000	1	.994	.003
	x3	15.255	2273.857	.000	1	.995	4216562.967
	x4	.950	91.988	.000	1	.992	2.586
	Constant	-206.570	18820.339	.000	1	.991	.000

a Variable(s) entered on step 1: x1, x2, x3, x4.

Where

B - the coefficients of the responsive variables and the constant of the equation

S.E. - Standard error

Wald - test statistic

d.f. – degree of freedom

Sig – Significant level

Substituting the values of β in the equation gives the probability function as:

$$\pi = \frac{e^{-206.57+134.03x_1-5.86x_2+15.26x_3+0.95x_4}}{1+e^{-206.57+134.03x_1-5.86x_2+15.26x_3+0.95x_4}}$$

The logistic regression model was tested at 5% significance level meaning that for a parameter to be significant in predicting a probability, the output of its significant level must be less than 5%. A value of 0% shows the p arameter to be hi ghly significant.

However, the output of all thc material properties (grading, LL, PI and CBR) is above 99%. This indicates that they are not significant in predicting thc probability that a gravel material will pass or not. Hence that probability function cannot be reliable.

As a result of this the logistic model could not be relied on for the predicting of probabilities. In view of the time one could not try other model and had to resort to ordinary proportions.

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

Based on the results of this study, the following conclusions may be drawn:

i) The proportion of samples passing G40 subbase is 26%

ii) The proportion of samples passing G30 subbase is 32%

iii) The proportion of samples passing G80 base is 2%

iv) The proportion of samples passing G60 base is 15%

v) NR and UWR have the highest number of gravel pits meeting the specification for G40 subbase layer

vi) UER had very few gravel pits meeting the specification for G40. This seems surprising considering the fact that they belong to the same geological formation and rainfall pattern as NR and UWR. It appears the sample size is a contributing factor.

vii) WR and CR have difficulty meeting PI and LL specification for natural gravel as a base layer

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viii) NR has the highest number of gravel pits meeting base specification

ix) Seven (7) regions could not have a single gravel pit meeting the MoT requirements for base material. However, if the specification is relaxed in the grading and just a little in the other three (3) parameters, the overall national percentage increases from 2%-15%.

x) Grading plays a very important part in deciding whether a natural gravel material meets the specification of subbase and base.

xi) It is almost impossible to find a natural gravel pit meeting the requirements of Otta seal without processing.

xii) The main problem of natural gravel material meeting the Otta seal specification arises because of grading.

xiii) However screening natural gravel through a single cycle raises the percentage meeting the Otta seal specification to 78% and that of 2 cycles of screening gives 100% compliance with grading requirements.

5.2 Recommendation

i) There should be research into the use of natural gravels meeting the specification for G60 and G30 as base and subbase respectively by constructing trial pavement sections and monitoring their performance. This is due to the fact that appreciable number of gravel pits met the requirements for G60 and hence maximise the utilisation of the gravel materials in the country.

ii) Natural gravel should be blended with other materials (stabilization) or crushed stone to improve the engineering properties as layer materials for subbase and base.

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APPENDIX A:
MOT Specification for Subbase and Base

Appenxix A1 Specification Table for Gravel after Placing and Compaction

Designation			TYPE 1	TYPE 2
Grading for Sub-base and Base; and including mechanically stabilized materials. (Used with bituminuous surfacing).	Sieves mm		% of weight passing	
	75		100	100
	37.5		80 – 100	80 – 100
	20		60 – 85	75 – 100
	5		30 – 55	30 – 75
	2		20 – 45	20 – 50
	0.425		8 – 26	8 – 33
	0.075		5 – 15	5 – 22
Sub-base (including mechanically stabilized materials)	Materials		**Gravels**	**Sands, silty and clayey sands**
	Plasticity	Liquid limit	Max. 35%	Max. 35%
		Plasticity Index	Max. 15%	Min. 5% – Max. 12%
		Plasticity Modulus	Max. 250	Max. 250
	Grading	Max. Size	75mm	-
		Uniformity Coefficient	Min. 5	Min. 5
		% passing 2 mm sieve	-	Max. 95%
		% passing 0.075 mm sieve	-	Min. 10 – Max. 30%
	Strength	CBR – 95% MDD, 4 day soak.(AASHTO)	Min.40%	Min.40%
		10% Fines (Wet)	Min. 50KN	Min. 50KN
Base (including mechanically stabilized materials)		**Grading**	**TYPE 1**	**TYPE 2**
	Plasticity	Liquid limit	Max. 25%	Max. 30%
		Plasticity Index	Max. 10%	Max. 15%
		Plasticity Modulus	Max. 200	Max. 400
	Strength	Los Angeles Abrasion	Max. 50%	Max. 50%
		Aggregate Crushing Value	Max. 35%	Max. 35%
		10% Fines (Wet)	Min. 50KN	Min. 50KN
		CBR – 95% MDD, 4 day soak.(AASHTO)	Min.80%	Min. 60%
	Note: For the base, Type 2 requirements are for use with surface dressing only and where traffic levels do not exceed 300 equivalent standard axles (8200 kg) per day.			

(Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 1991,MRH, Ghana).

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Appenxix A1 Specification Table for Gravel after Placing and Compaction

Designation			TYPE 1	TYPE 2
Grading for Sub-base and Base; and including mechanically stabilized materials. (Used with bituminuous surfacing).	Sieves mm		% of weight passing	
	75		100	100
	37.5		80 – 100	80 – 100
	20		60 – 85	75 – 100
	5		30 – 55	30 – 75
	2		20 – 45	20 – 50
	0.425		8 – 26	8 – 33
	0.075		5 – 15	5 – 22
Sub-base (including mechanically stabilized materials)	Materials		**Gravels**	**Sands, silty and clayey sands**
	Plasticity	Liquid limit	Max. 35%	Max. 35%
		Plasticity Index	Max. 15%	Min. 5% – Max. 12%
		Plasticity Modulus	Max. 250	Max. 250
	Grading	Max. Size	75mm	-
		Uniformity Coefficient	Min. 5	Min. 5
		% passing 2 mm sieve	-	Max. 95%
		% passing 0.075 mm sieve	-	Min. 10 – Max. 30%
	Strength	CBR – 95% MDD, 4 day soak.(AASHTO)	Min.40%	Min.40%
		10% Fines (Wet)	Min. 50KN	Min. 50KN
Base (including mechanically stabilized materials)		**Grading**	**TYPE 1**	**TYPE 2**
	Plasticity	Liquid limit	Max. 25%	Max. 30%
		Plasticity Index	Max. 10%	Max. 15%
		Plasticity Modulus	Max. 200	Max. 400
	Strength	Los Angeles Abrasion	Max. 50%	Max. 50%
		Aggregate Crushing Value	Max. 35%	Max. 35%
		10% Fines (Wet)	Min. 50KN	Min. 50KN
		CBR – 95% MDD, 4 day soak.(AASHTO)	Min.80%	Min. 60%
	Note: For the base, Type 2 requirements are for use with surface dressing only and where traffic levels do not exceed 300 equivalent standard axles (8200 kg) per day.			

(Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 1991,MRH, Ghana).

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Material properties	Material Class			
	G80	G60	G40	G30
CBR (%)	80	60	40	30
CBR Swell (%)	0.25	0.5	0.5	1.0
Grading % Passing Sieve Size (mm)				
75	100	100		
37.5	80 - 100	80 - 100		
20	60 - 85	75 - 100		
10	45 - 70	45 - 90		
5.0	30 - 55	30 - 75		
2.0	20 - 45	20 - 50		
0.425	8 - 26	8 - 33		
0.075	5 – 15	5 – 22		
Grading Modulus (min)	2.15	1.95	1.5	1.25
Maximum size (mm)	53.0	63.0	75.0	2/3rd layer thickness
Atterberg Limits				
Liquid Limit (%) (max)	25	30	30	35
Plasticity Index (%) (max)	10	12	14	16
Linear Shrinkage (%) (max)	5	6	7	8
Plasticity modulus (max)	200	250	250	250
Other properties				
10%Fines (kN) (min)	80	50	-	-
Ratio dry/soaked 10%Fines (min)	0.6	0.6		

Notes:

All CBR's will be determined at the field density specified for the layer in which the material is used.

All Atterberg limits will be determined using GHA S6) (Section **Error! Reference source not found.**)

All grading specifications are applicable after placing and compaction. Grading curves shall be smooth curves within the specified envelopes and approximately parallel to the envelopes.

Grading Modulus (GM) = 300 – (percentage passing 2.0 + 0.425 + 0.075 mm sieves) / 100

Plasticity modulus = Plasticity Index x percentage passing 0.425 mm sieve

G80 Base course G60 Base course for low traffic roads

G40 Base course for sealed rural access roads G30 Subbase

Subbase

Source: Clause 12.3 of the Standard Specification for Roads and Bridges, 2006,MOT, Ghana).

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APPENDIX B:
LOCATIONS OF NATURAL GRAVELS

Table B1: Gravel locations in the Northern Region

Sample Identification	District	Road Name/Pit
NR-1	Salaga	Tamale - Salaga
NR-2	Bimbila	Yendi - Bimbila
NR-3	Tamale	Tamale - Kintampo
NR-4	Central Gonja	Tamale - Bupei
NR-5	Zabzugu-Tatale	Zabzugu - Tatale
NR-6	Saboba-Chereponi	Yendi - Saboba
NR-7	Yendi District	Tamale - Yendi
NR-8	Savelugu-Nanton	Tamale - Bolga
NR-9	Yendi	Tamale-yendi
NR-10	Yendi	Tamale-Yendi
NR-11	Damongo	Damongo-Buachipe
NR-12	Bole	Sawla-Dabgrigu
NR-13	Bole	Sawla-Dabgrigu
NR-14	Tolon	Tolon-Ypeligu
NR-15	Tamale	Nylanliga-Yapei
NR-16	Salaga	Kusugu-Tulewe
NR-17	Sboba Chereponi	Wandugu-Kasunayily
NR-18	Savelugu Nanton	Sap-Palari
NR-19	Savelugu Nanton	Tali-Kulay
NR-20	Tolon Kumbugu	-
NR-21	Gushiegu	-
NR-22	Bimbila	-
NR-23	Tamale	-
NR-24	East Mamprusi	-
NR-25	Yendi	-
NR-26	Saboba Chereponi	-
NR-27	West Gonja	-
NR-28	NA	Fufulso-Sawla
NR-29	NA	Fufulso-Sawla
NR-30	NA	Fufulso-Sawla
NR-31	NA	Fufulso-Sawla
NR-32	NA	Fufulso-Sawla
NR-33	NA	Fufulso-Sawla
NR-34	NA	Fufulso-Sawla
NR-35	NA	Fufulso-Sawla
NR-36	NA	Fufulso-Sawla
NR-37	NA	Fufulso-Sawla
NR-38	NA	Fufulso-Sawla
NR-39	NA	Fufulso-Sawla
NR-40	NA	Fufulso-Sawla

Table B1: Gravel locations in the Northern Region

Sample Identification	District	Road Name/Pit
NR-41	NA	Fufulso-Sawla
NR-42	NA	Fufulso-Sawla
NR-43	NA	Fufulso-Sawla
NR-44	NA	Fufulso-Sawla
NR-45	NA	Fufulso-Sawla
NR-46	NA	Bamboi-Bole
NR-47	NA	Bamboi-Bole
NR-48	NA	Bamboi-Bole
NR-49	NA	Bamboi-Bole
NR-50	NA	Bamboi-Bole
NR-51	NA	Bamboi-Bole
NR-52	NA	Bamboi-Bole
NR-53	NA	Bamboi-Bole
NR-54	NA	Bamboi-Bole
NR-55	NA	Bamboi-Bole
NR-56	NA	Bamboi-Bole
NR-57	NA	Bamboi-Bole
NR-58	NA	Bamboi-Bole
NR-59	NA	Bamboi-Bole
NR-60	NA	Bamboi-Bole
NR-61	NA	Bamboi-Bole
NR-62	NA	Bamboi-Bole
NR-63	NA	Bamboi-Bole
NR-64	NA	Kintampo-Paga/ Nyangwuripe
NR-65	NA	Kintampo-Paga/
NR-66	NA	Kintampo-Paga/Gushie
NR-67	NA	Kintampo-Paga/Nasia
NR-68	NA	Kintampo-Paga/

Table B2: Gravel locations in the Upper West Region

Sample Identification	District	Road Name/Pit
UWR-1	Lawra	Bo-Tantuo-Kokoligu
UWR- 2	Lawra	Nandom-Ketuo-Tantuo
UWR- 3	Nadowli	Daffiama-Kunzokala-Dapouri
UWR- 4	Nadowli	Nadowli-Kaeggo-Nator
UWR- 5	Sissala East	Tumu-Kupulima-Leo Rd
UWR- 6	Sissala West	Han-Zini-Gwallo Rd
UWR- 7	Jirapa/Lambussie	Jirapa-Dowene Road
UWR- 8	Jirapa/Lambussie	WA-Jirapa-Hamile Rd
UWR- 9	Nadowli	Wa-Sombo-Jirapa
UWR -10	Jirapa/Lambussie	Jirapa- Babile
UWR -11	Wa	Wa-Han Road
UWR -12	Nadowli	WA-Sombo-Jirapa Rd
UWR -13	Wa	Bamboi-Bole Rd
UWR -14	Jirapa/Lambussie	Jirapa-Dowene Road
UWR -15	Nadowli	Nadowli-Tangasia
UWR -16	Nadowli	Daffiama-Kunzokala-Dapouri
UWR -17	NA	Wa-Han
UWR -18	NA	Wa-Han
UWR -19	NA	Wa-Han
UWR -20	NA	Wa-Han
UWR -21	NA	Wa-Han
UWR -22	NA	Wa-Han
UWR -23	NA	Wa-Han
UWR -24	NA	Wa-Han
UWR -25	NA	Tumu-Lawra
UWR -26	NA	Tumu-Lawra
UWR -27	NA	Tumu-Lawra
UWR -28	NA	Tumu-Lawra
UWR -29	NA	Tumu-Lawra
UWR -30	NA	Tumu-Lawra
UWR -31	NA	Tumu-Lawra
UWR -32	NA	Tumu-Lawra
UWR -33	NA	Tumu-Lawra
UWR -34	NA	Tumu-Lawra
UWR -35	NA	Tumu-Lawra
UWR -36	NA	Tumu-Lawra
UWR -37	NA	Tumu-Lawra
UWR -38	NA	Tumu-Lawra
UWR -39	NA	Tumu-Lawra
UWR -40	NA	Navrongo-Tumu

Table B2: Gravel locations in the Upper West Region

Sample Identification	District	Road Name/Pit
UWR -41	NA	Navrongo-Tumu
UWR -42	NA	Navrongo-Tumu
UWR -43	NA	Navrongo-Tumu
UWR -44	NA	Navrongo-Tumu
UWR -45	NA	Navrongo-Tumu
UWR -46	NA	Navrongo-Tumu
UWR -47	NA	Navrongo-Tumu
UWR -48	NA	Navrongo-Tumu
UWR -49	NA	Navrongo-Tumu
UWR -50	NA	Navrongo-Tumu
UWR -51	NA	Navrongo-Tumu
UWR -52	NA	Navrongo-Tumu
UWR -53	NA	Navrongo-Tumu
UWR -54	NA	Navrongo-Tumu
UWR -55	NA	Navrongo-Tumu
UWR -56	NA	Navrongo-Tumu
UWR -57	NA	Navrongo-Tumu

Table B3: Gravel locations in the Upper East Region

Sample Identification	District	Road Name/Pit
UER-1	Garutempane	Deega - Kukalasa
UER-2	Garutempane	Garu- Wurinyagu
UER-3	Garutempane	Tempane- Yabragu
UER-4	Talansi - Namdam	Nangodi-Sheaga
UER-5	Talansi - Namdam	Winkongo- Sheaga
UER-6	Bawku West	Kubori- Yarigu
UER-7	Bawku East	Kulegugu-Kulpegu
UER-8	Kasena - Nankana	Paga-Crocodile Pond
UER-9	Kasena - Nankana	Kajio- Gian
UER-10	Bolgatanga	Zaare-Gowire
UER-11	NA	Navrongo-Tumu
UER-12	NA	Navrongo-Tumu
UER-13	NA	Woriyanga-Tempane
UER-14	NA	Yanatinga Jn. Yanatinga
UER-15	NA	Worikamba-Yizidug
UER-16	NA	Dengu Jn- Dengu
UER-17	NA	Winkogo-Tongo-Pelungu
UER-18	NA	Kintampo-Paga/ Shiregu
UER-19	NA	Kintampo-Paga/ Kamdinga

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Table B4: Gravel locations in the Ashanti Region

Sample Identification	District	Road Name/Pit
AR-1	Atwima Mponua	Kwanfinfin - Kotokuom
AR-2	Atwima Nwabiagya	Wioso - Amanchia
AR-3	Amansie West	Mim Jn - Agroyesum
AR-4	Amansie East	Pakyi - Antoawakrom
AR-5	Afigya Sekyere	Agona - Wiamoase
AR-6	Ahafo Ano South	Sabronum - Ahwerewase
AR-7	Ahafo Ano South	Kumso Camp - Bonkronu
AR-8	Ahafo Ano North	Akwasiase - Asusyie
AR-9	Obuasi	Obuasi - Akrofuom
AR-10	Mampong	Hwediem - Nsuta
AR-11	Amansie East	SDA Sec. Sch. - Adonku
AR-12	Ejura Sekyredumase	Aframso - Sekyeredumase
AR-13	Asante Akim North	Konongo - Duase
AR-14	Asante Akim South	Asankare - Amuama-Praso
AR-15	Kwabre District	Hemang - Ejuratia- Mpobi
AR-16	Atwima Kwamoma	Nyameani - Bcposo
AR-17	Ejusu Juabeng	Kubease - Motokrodua
AR-18	Atwima Kwanhuma	Kokoben Pit
AR-19	Amansie East	Pekyi No2 Pit
AR-20	Atwima Nwabiagya	Nkontomere Pit
AR-21	Atwima Kwanhuma	Techiman Merewadwa Pit
AR-22	Atwima Kwanhuma	Trede-Yabi Road
AR-23	Atwima Kwanhuma	Akosomo Pit
AR-24	Kwabre	Asonomaso Pit
AR-25	Effigya Sekyere	Kona Pit
AR-26	Kwabre	Tanodomase Pit
AR-27	Kumasi	Daabaa Pit
AR-28	Atwima Kwanhuma	Akosomo-Dakoro Road
AR-29	Amansie East	Adumasa Pit
AR-30	NA	Kumasi-Techiman/Akuroforom
AR-31	NA	Kumasi-Techiman/Kodie
AR-32	NA	Kumasi-Techiman/Akom
AR-33	NA	Kumasi-Techiman/Ahenkro
AR-34	NA	Kumasi-Techiman/Asikaman
AR-35	NA	Kumasi-Techiman/Kwantoma
AR-36	NA	Kumasi-Techiman/Kwantoma
AR-37	NA	Kumasi-Techiman/Bremawuokrom
AR-38	NA	Kumasi-Techiman/Kwantoma
AR-39	NA	Kumasi-Techiman/Brakyere
AR-40	NA	Kumasi-Techiman/Aburokyire A

Table B4: Gravel locations in the Ashanti Region

Sample Identification	District	Road Name/Pit
AR-41	NA	Kumasi-Techiman/Aburokyire B
AR-42	NA	Kumasi-Techiman/
AR-43	NA	Kumasi-Techiman/
AR-44	NA	Kumasi-Techiman/
AR-45	NA	Kumasi-Techiman/Kobreso
AR-46	NA	Kumasi-Techiman/Mantukwa
AR-47	NA	Kumasi-Techiman/Medokwae
AR-48	NA	Kumasi-Techiman/Nkenkasu
AR-49	NA	Kumasi-Techiman/Nkenkasu
AR-50	NA	Kumasi-Techiman/Akumadan
AR-51	NA	Kumasi-Techiman/
AR-52	NA	Kumasi-Techiman/Afrantwo 5
AR-53	NA	Kumasi-Techiman/Afrantwo
AR-54	NA	Kumasi-Techiman/
AR-55	NA	Kumasi-Techiman/Tanoso
AR-56	NA	Kumasi-Techiman/Tadieso A
AR-57	NA	Kumasi-Techiman/Tadieso B
AR-58	NA	Kumasi-Techiman/
AR-59	NA	Kumasi-Techiman/Akusumansu
AR-60	NA	Kumasi-Techiman/Panhuyesu
AR-61	NA	Kumasi-Techiman/Akusumansu
AR-62	NA	Kumasi-Techiman/Yepimso
AR-63	NA	Kumasi-Techiman/Awurapata
AR-64	NA	Oforikrom-Asokwa Bypass/Tetrefu
AR-65	NA	Oforikrom-Asokwa Bypass/Sewua
AR-66	NA	Oforikrom-Asokwa Bypass/Akwaduo
AR-67	NA	Adagya
AR-68	NA	Anwiannkwanta-Kumasi/ Anwiannkwanta
AR-69	NA	Anwiannkwanta-Kumasi/Supan
AR-70	NA	Anwiannkwanta-Kumasi/Afrentia
AR-71	NA	Anwiannkwanta-Kumasi/
AR-72	NA	Anwiannkwanta-Kumasi/Paa
AR-73	NA	Anwiannkwanta-Kumasi/Ofoase Kokoben
AR-74	NA	Anwiannkwanta-Kumasi/Kotei
AR-75	NA	Anwiannkwanta-Kumasi/

Table B5: Gravel locations in the Western Region

Sample Identification	District	Road Name/Pit
WR-1	Wassa Amenfi East	Ayanfuri-Diaso
WR-2	Wassa Amenfi East	Adonoe
WR-3	Wassa Amenfi East	Kofikrom
WR-4	Jomoro	Ahoaka
WR-5	Jomoro	Azuleti-Etweakor
WR-6	Jomoro	Mile 5-Navrong
WR-7	Sefwi Wiawso	Benchima -Nkatieso
WR-8	Sefwi Wiawso	Donkoto
WR-9	Wassa West	Low Cost -Tarkwa
WR-10	Wassa West	Aboso-Wassa Nkran
WR-11	Ahanta West	Egyam Jn -Kanfakrom
WR-12	Ahanta West	Aboadze-Ayiem Rd
WR-13	Nzema East	Anibre-Kokofre
WR14	Nzema East	Axim - Elubo
WR-15	Juabeso	Sefwi -Benchema Jn
WR-16	Juabeso	Benchema Jn-Sayereano
WR-17	Juabeso	Outskirt of Juabeso Town
WR-18	Mpohor Wassa East	Apowa-Benso
WR-19	Mpohor Wassa East	Adiembra-Kumasi F/R
WR-20	NA	Bawdie-Asankragua/
WR-21	NA	Bawdie-Asankragua/
WR-22	NA	Bawdie-Asankragua/
WR-23	NA	Bawdie-Asankragua/
WR-24	NA	Bawdie-Asankragua/
WR-25	NA	Bawdie-Asankragua/
WR-26	NA	Bawdie-Asankragua/
WR-27	NA	Bawdie-Asankragua/
WR-28	NA	Bawdie-Asankragua/
WR-29	NA	Bawdie-Asankragua/
WR-30	NA	Bawdie-Asankragua/
WR-31	NA	Bawdie-Asankragua/
WR-32	NA	Bawdie-Asankragua/
WR-33	NA	Bawdie-Asankragua/
WR-34	NA	Bawdie-Asankragua/
WR-35	NA	Bawdie-Asankragua/
WR-36	NA	Bawdie-Asankragua/
WR-37	NA	Axim Jn-Tarkwa
WR-38	NA	Axim Jn-Tarkwa
WR-39	NA	Axim Jn-Tarkwa
WR-40	NA	Axim Jn-Tarkwa

Table B5: Gravel locations in the Western Region

Sample Identification	District	Road Name/Pit
WR-41	NA	Axim Jn-Tarkwa
WR-42	NA	Axim Jn-Tarkwa
WR-43	NA	Axim Jn-Tarkwa
WR-44	NA	Axim Jn-Tarkwa
WR-45	NA	Axim Jn-Tarkwa
WR-46	NA	Axim Jn-Tarkwa
WR-47	NA	Axim Jn-Tarkwa
WR-48	NA	Axim Jn-Tarkwa
WR-49	NA	Axim Jn-Tarkwa
WR-50	NA	Tarkwa-Bogoso
WR-51	NA	Tarkwa-Bogoso
WR-52	NA	Tarkwa-Bogoso
WR-53	NA	Tarkwa-Bogoso
WR-54	NA	Bogoso-Asawinso
WR-55	NA	Bogoso-Asawinso
WR-56	NA	Bogoso-Asawinso
WR-57	NA	Bogoso-Asawinso
WR-58	NA	Bogoso-Asawinso
WR-59	NA	Bogoso-Asawinso
WR-60	NA	Bogoso-Asawinso
WR-61	NA	Bogoso-Asawinso
WR-62	NA	Bogoso-Asawinso
WR-63	NA	Bogoso-Asawinso
WR-64	NA	Bogoso-Asawinso
WR-65	NA	Bogoso-Asawinso
WR-66	NA	Bogoso-Asawinso
WR-67	NA	Bogoso-Asawinso
WR-68	NA	Bogoso-Asawinso
WR-69	NA	Bogoso-Asawinso
WR-70	NA	Bogoso-Asawinso
WR-71	NA	Bogoso-Asawinso
WR-72	NA	Bogoso-Asawinso

Table B6: Gravel locations in the Brong Ahafo Region

Sample Identification	District	Road Name/Pit
BAR-1	Sunyani	Sunyani- Techiman
BAR-2	Sunyani	Sunyani- Techiman
BAR-3	Sunyani	Sunyani- Techiman
BAR-4	Sunyani	Sunyani- Techiman
BAR-5	Sunyani	Sunyani- Techiman
BAR-6	Sunyani	Sunyani- Techiman
BAR-7	Sunyani	Sunyani- Techiman
BAR-8	Sunyani	Sunyani- Techiman
BAR-9	Sunyani	Sunyani- Techiman
BAR-10	Sunyani	Sunyani- Techiman
BAR-11	Sunyani	Sunyani- Techiman
BAR-12	Tain	Nsokaw-Hani
BAR-13	Tain	Nsokaw-Hani
BAR-14	Tain	Brekum-Seikwa
BAR-15	Kintampo North	Amoma Jn-Effuman
BAR-16	Kintampo North	Ntankoro-Abudwen-Kobeda
BAR-17	NA	Gambia No.2-Kyeremasu/
BAR-18	NA	Gambia No.2-Kyeremasu/
BAR-19	NA	Gambia No.2-Kyeremasu/
BAR-20	NA	Gambia No.2-Kyeremasu/
BAR-21	NA	Kintampo-Paga/Babatorkuma
BAR-22	NA	Kintampo-Paga/ Kawampe
BAR-23	NA	Kintampo-Paga/ Aberewa

Table B7: Gravel locations in the Eastern Region

Sample Identification	District	Road Name/Pit
ER-1	Birim South	Abenase- Juaha
ER-2	Birim South	Abenase- Juaha
ER-3	New Juaben	Nyamekrom
ER-4	New Juaben	Nana Asafo Adjei
ER-5	New Juaben	Nana Asafo Adjei
ER-6	New Juaben	Nana Asafo Adjei
ER-7	New Juaben	Nana Asafo Adjei
ER-8	Kwaebibirim	Akwatia
ER-9	Kwahu West	Fodea-Bebease
ER-10	Suhum Kraboa oaltar	Suhum
ER-11	NA	Nsawam-Apedwa/Sakyikrom
ER-12	NA	Nsawam-Apedwa/Dzatsui
ER-13	NA	Nsawam-Apedwa/Bethsaida
ER-14	NA	Nsawam-Apedwa/Teacher Mante
ER-15	NA	Nsawam-Apedwa/Gorjiase 1
ER-16	NA	Nsawam-Apedwa/Gorjiase 2
ER-17	NA	Pantang-Mamfe/Kitase
ER-18	NA	Pantang-Mamfe/Kitase
ER-19	NA	Pantang-Mamfe/Kitase
ER-20	NA	Apedwa-Bunso/Akooko 1
ER-21	NA	Apedwa-Bunso/Akooko 2
ER-22	NA	Apedwa-Bunso/Asafo
ER-23	NA	Apedwa-Bunso/Atwemamena
ER-24	NA	Apedwa-Bunso/Anyinasin

Table B8: Gravel locations in the Central Region

Sample Identification	Distri CR-ct	Road Name/Pit
CR-1	Ajumako - Enyan - Essiam	Ajumako - Eshiem - Besease
CR-2	Asikuma - Odoben - Brakwa	Asikuma - Kuntunase
CR-3	Twifo Hemang Lower Denkyira	Hemang - Baakondidi
CR-4	Gomoa	Apam - Mamford
CR-5	Upper Denkyira	Dunkwa - Kuntunase
CR-6	Komenda Edina - Eguafo - Abrem	Ataabadze Jn - Ataabadze
CR-7	Abura Asebu - Kwamankese	Abakrampa Jn - Asunasi
CR-8	Mfanteman	Eyisam - Nanaben
CR-9	Ewutu - Efutu - Senya	Potsin Jn - Awomberew
CR-10	Assin South	Assin Nyankomase Ahenkro - Tumfokor
CR-11	Cape Coast	Moree Jn - Moree
CR-12	Agona	Bobikuma - Nyarkrom
CR-13	Twifo Hemang Lower Denkyira	Dunkwa-Twifo Praso
CR-14	Twifo Hemang Lower Denkyira	Dunkwa-Twifo Praso
CR-15	Twifo Hemang Lower Denkyira	Dunkwa-Twifo Praso
CR-16	Awutu Effutu Senya	kasoa-Bawjiase
CR-17	Awutu Effutu Senya	kasoa-Bawjiase
CR-18	Gomoa	Akoti Jn- Senya Bereku
CR-19	Gomoa	Akoti Jn- Senya Bereku
CR-20	Upper Denkyira	Ayenfuri-Diaso
CR-21	Assin North	Foso-Twifo Praso
CR-22	Assin North	Foso-Twifo Praso
CR-23	Awutu Effutu Senya	Senya - Feteh
CR-24	Abura Asebu Kwamankese	District Assembly
CR-25	Asikuma Odoben Brakwa	Asikuma -Kuntunase
CR-26	Twifo Hemang Lower Denkyira	Hemang-Baakondidi

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Table B8: Gravel locations in the Central Region

Sample Identification	District	Road Name/Pit
CR-27	NA	Accra-Cape Coast/Nkwantanan 1
CR-28	NA	Accra-Cape Coast/Nkwantanan 2
CR-29	NA	Accra-Cape Coast/Bududuram
CR-30	NA	Accra-Cape Coast/Fetteh Kakraba 1
CR-31	NA	Accra-Cape Coast/Fetteh Kakraba 2
CR-32	NA	Accra-Cape Coast/Awutu
CR-33	NA	Accra-Cape Coast/Akoti
CR-34	NA	Accra-Cape Coast/Akramang
CR-35	NA	Accra-Cape Coast/Dominase
CR-36	NA	Accra-Cape Coast/Potsin
CR-37	NA	Accra-Cape Coast/Okyereko
CR-38	NA	Accra-Cape Coast/Gomoa Amanfi
CR-39	NA	Accra-Cape Coast/Gomoa Simbrofo
CR-40	NA	Accra-Cape Coast/Gomoa Otse Jukwa
CR-41	NA	Accra-Cape Coast/Gwan
CR-42	NA	Accra-Cape Coast/Gomoa Amanfrom
CR-43	NA	Accra-Cape Coast/Odumase
CR-44	NA	Accra-Cape Coast/Gomoa Manso
CR-45	NA	Accra-Cape Coast/Ekumfi Egyankwa
CR-46	NA	Accra-Cape Coast/Ekumfi Bogyano
CR-47	NA	Accra-Cape Coast/Ekumfi Twa
CR-48	NA	Accra-Cape Coast/Ekumfi Tsafo
CR-49	NA	Accra-Cape Coast/Ekumfi Eyisam
CR-50	NA	Accra-Cape Coast/Ekumfi Edukuma
CR-51	NA	Accra-Cape Coast/Ekumfi Akwakrom
CR-52	NA	Accra-Cape Coast/Kuntu
CR-52	NA	Accra-Cape Coast/Afragua
CR-54	NA	Accra-Cape Coast/Ekurabadze
CR-55	NA	Kasoa
CR-56	NA	Kasoa

Table B9: Gravel locations in the Volta Region

Sample Identification	District	Road Name/Pit
VR-1	South Tongui	Bakpa
VR-2	South-Tongui	Agortoe-Tregbui
VR-3	South-Tongui	Agorta - Agorve
VR-4	Kadjebi	Kadjebi-Djinijiniso
VR-5	Kadjebi	Kadjebi-Suminanteng
VR-6	Kadjebi	Dodi - Mempasem
VR-7	Adaklu Anyigbe	Ziope
VR-8	Adaklu Anyigbe	Keryime - Adaklu-Torda
VR-9	Jasikan	Jasikan-Bodada
VR-10	Ho	Kpedze-Ashant Kpoata
VR-11	Ho	Bame - Djulikpuita
VR-12	NA	Sogakope-Akatsi/
VR-13	NA	Sogakope-Akatsi/
VR-14	NA	Sogakope-Akatsi/
VR-15	NA	Sogakope-Akatsi/
VR-16	NA	Sogakope-Akatsi/
VR-17	NA	Sogakope-Akatsi/
VR-18	NA	Sogakope-Akatsi/
VR-19	NA	Sogakope-Akatsi/
VR-20	NA	Sogakope-Akatsi/
VR-21	NA	Sogakope-Akatsi/
VR-22	NA	Sogakope-Akatsi/
VR-23	NA	Sogakope-Akatsi/
VR-24	NA	Sogakope-Akatsi/
VR-25	NA	Brewaniase-Oti Damanko/
VR-26	NA	Brewaniase-Oti Damanko/
VR-27	NA	Brewaniase-Oti Damanko/
VR-28	NA	Brewaniase-Oti Damanko/
VR-29	NA	Brewaniase-Oti Damanko/
VR-30	NA	Brewaniase-Oti Damanko/
VR-31	NA	Brewaniase-Oti Damanko/
VR-32	NA	Brewaniase-Oti Damanko/
VR-33	NA	Brewaniase-Oti Damanko/
VR-34	NA	Brewaniase-Oti Damanko/
VR-35	NA	Brewaniase-Oti Damanko/
VR-36	NA	Brewaniase-Oti Damanko/
VR-37	NA	Brewaniase-Oti Damanko/
VR-38	NA	Brewaniase-Oti Damanko/
VR-39	NA	Brewaniase-Oti Damanko/

Table B10: Gravel locations in the Greater Accra Region

Sample Identification	District	Road Name/Pit
GAR-1	Ga East	Pantang-Mamfe/Ayi Mensah 1
GAR-2	Ga East	Pantang-Mamfe/ Ayi Mensah 1
GAR-3	Ga East	Pantang-Mamfe/ Ayi Mensah 1
GAR-4	Ga East	Pantang-Mamfe/ Ayi Mensah 1
GAR-5	Ga East	Pantang-Mamfe/ Ayi Mensah 2
GAR-6	Ga East	Pantang-Mamfe/ Ayi Mensah 2
GAR-7	Ga East	Pantang-Mamfe/ Ayi Mensah 2
GAR-8	Ga East	Pantang-Mamfe/ Ayi Mensah 2
GAR-9	Ga East	Pantang-Mamfe/ Ayi Mensah 2
GAR-10	Ga East	Pantang-Mamfe/Otinibi
GAR-11	Ga East	Pantang-Mamfe/Otinibi
GAR-12	Ga East	Pantang-Mamfe/Otinibi
GAR-13	Ga East	Pantang-Mamfe/Otinibi
GAR-14	Ga East	Pantang-Mamfe/Otinibi
GAR-15	Ga East	Pantang-Mamfe/Otinibi
GAR-16	NA	Tema Community 25
GAR-17	NA	Afienya
GAR-18	NA	Mobole
GAR-19	NA	Otsebleku
GAR-20	NA	Katamanso
GAR-21	NA	Katamanso

APPENDIX C:
COMPARING GRADING, CBR AND ATTERBERG LIMITS OF NATURAL GRAVELS WITH MOT G40 SUBBASE REQUIREMENTS

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Table C1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	26 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI< 14	LL< 30	CBR> 40
NR-1	100	90	83	69	59	34	23	17	11	21.7	13.3	8.4	N/A	Passed	Passed	Passed	N/A
NR-2	100	93	87	68	49	23	15	13	11	24.3	15.7	8.6	N/A	Passed	Passed	Passed	N/A
NR-3	100	92	84	66	46	20	14	12	10	21.8	13.6	8.2	N/A	Failed	Passed	Passed	N/A
NR-4	100	91	82	63	51	30	23	20	17	22.6	15.1	7.5	N/A	Passed	Passed	Passed	N/A
NR-5	100	89	76	55	45	32	28	27	25	27.2	15.4	11.8	N/A	Passed	Passed	Passed	N/A
NR-6	100	98	91	77	65	44	34	29	23	26.3	15.4	10.9	N/A	Failed	Passed	Passed	N/A
NR-7	100	100	96	80	59	26	20	18	13	19.6	13.2	6.4	N/A	Failed	Passed	Passed	N/A
NR-8	100	97	90	77	64	33	21	17	14	33.5	20.7	12.8	N/A	Failed	Passed	Failed	N/A
NR-9	100		78		41.1	22.3	14.6	12.4	10.4	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
NR-10	100		95		58.5	33.8	23.9	20.2	16.8	N/A	N/A	11.1	N/A	Failed	Passed	N/A	N/A
NR-11	100		92		57.7	30.2	19.5	16.7	13	N/A	N/A	13.3	N/A	Failed	Failed	N/A	N/A
NR-12	100		90		68.7	46.8	42	38.8	25.6	N/A	N/A	17.3	N/A	Failed	Failed	N/A	N/A
NR-13	100		96		70.6	34.2	25.6	23.2	15.5	N/A	N/A	23.7	N/A	Failed	Failed	N/A	N/A
NR-14	100		87		53.6	27.2	17.7	13.9	9	N/A	N/A	13.3	N/A	Passed	Passed	N/A	N/A
NR-15	100		83		53.2	33	27.5	25.5	22.6	N/A	N/A	14.3	N/A	Failed	Failed	N/A	N/A
NR-16	100		99.5		88.4	40	24.2	21.5	14.4	N/A	N/A	12.3	N/A	Failed	Passed	N/A	N/A
NR-17	100		94		56.9	34.4	26.8	24	13.9	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
NR-18	100		97		70.9	33.6	24.8	23.4	19.4	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
NR-19	100		84		29.7	17.7	14	13	10.9	N/A	N/A	14.5	N/A	Failed	Failed	N/A	N/A
NR-20	100		99		93	63.2	47.2	38.1	33	N/A	N/A	16.1	N/A	Failed	Failed	N/A	N/A

Table C1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI< 14	LL< 30	CBR> 40
NR-21		100	100	85	42	24	18	16	12	N/A	N/A	16.4	N/A	Passed	Failed	N/A	N/A
NR-22		100	100	99	73	38	29	26	20	N/A	N/A	14	N/A	Failed	Passed	N/A	N/A
NR-23		100	100	97	73	39	30	28	19	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
NR-24		100	100	90	56	31	30	30	21	N/A	N/A	7.7	N/A	Passed	Passed	N/A	N/A
NR-25		100	100	97	57	33	27	26	19	N/A	N/A	3.9	N/A	Failed	Passed	N/A	N/A
NR-26		100	100	66	43	30	26	24	19	N/A	N/A	10.3	N/A	Passed	Passed	N/A	N/A
NR-27		100	100	94	56	31	25	24	17	N/A	N/A	14.3	N/A	Failed	Failed	N/A	N/A
NR-28	100	92	81	64	46	34		30	19	17.2	12.3	4.9	85	Passed	Passed	Passed	Passed
NR-29	100	91	78	53	36	31		29	14	17.8	12.3	5.5	75	Passed	Passed	Passed	Passed
NR-30		100	82	60	45	37		32	14	14.8	10.1	4.7	56	Passed	Passed	Passed	Passed
NR-31	100	98	84	63	42	30		26	13	17.8	10.6	7.2	80	Passed	Passed	Passed	Passed
NR-32	100	97	91	84	76	45		38	20	17.4	12.8	4.6	42	Failed	Passed	Passed	Passed
NR-33	100	95	92	79	58	32		20	6	17.4	12.7	4.7	45	Passed	Passed	Passed	Passed
NR-34	100	95	91	80	48	25		18	7	18.2	12.5	5.7	55	Passed	Passed	Passed	Passed
NR-35	100	96	93	78	60	40		32	23	17	13.5	3.5	32	Passed	Passed	Passed	Failed
NR-36		100	95	81	50	29		25	12	NP	NP	NP	35	Passed	Passed	Passed	Failed
NR-37	100	96	79	68	46	27		19	7	26.6	18	8.6	55	Passed	Passed	Passed	Passed
NR-38		100	91	84	64	45		36	14	21.2	14.7	6.5	50	Failed	Passed	Passed	Passed
NR-39	100	89	78	54	38	25		20	15	24.6	18.8	5.8	51	Passed	Passed	Passed	Passed
NR-40	100	96	89	68	40	25		11	5	22.2	17.2	5	65	Passed	Passed	Passed	Passed

Table C1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 14	LL≤ 30	CBR≥ 40
NR-41	100	97	92	86	57	33		25	19	21.8	14.9	6.9	23	Passed	Passed	Passed	Failed
NR-42	100	95	83	72	54	29		21	17	23.8	18.2	5.6	20	Passed	Passed	Passed	Failed
NR-43	100	95	89	76	50	43		29	13	19.8	13.8	6	33	Passed	Passed	Passed	Failed
NR-44		100	93	90	75	48		34	11	19.4	13.9	5.5	46	Passed	Passed	Passed	Passed
NR-45	100	97	92	80	59	37		22	9	17.8	13.4	4.4	60	Passed	Passed	Passed	Passed
NR-46		100	85	55	42	31	25	17	7	19	14	5	95	Passed	Passed	Passed	Passed
NR-47		100	90	70	41	24	20	18	14	18	13	5	69	Passed	Passed	Passed	Passed
NR-48		100	95	75	66	43	41	39	32	57	25	31	50	Failed	Failed	Failed	Passed
NR-49		100	91	70	40	20	14	15	13	19	13	6	90	Failed	Passed	Passed	Passed
NR-50		100	89	74	49	29	23	21	11	NP	NP	NP	50	Passed	Passed	Passed	Passed
NR-51		100	94	79	31	16	13	9	3	NP	NP	NP	50	Failed	Passed	Passed	Passed
NR-52		100	98	79	49	24	23	14	9	NP	NP	NP	118	Passed	Passed	Passed	Passed
NR-53		100	99	84	41	22	18	12	5	NP	NP	NP	125	Passed	Passed	Passed	Passed
NR-54		100	100	90	56	36	29	20	11	NP	NP	NP	N/A	Passed	Passed	Passed	N/A
NR-55		100	100	89	57	33	27	19	7	NP	NP	NP	N/A	Passed	Passed	Passed	N/A
NR-56		100	100	88	45	24	20	14	7	NP	NP	NP	200	Passed	Passed	Passed	Passed
NR-57		100	94	69	37	33	28	16	5	NP	NP	NP	32	Passed	Passed	Passed	Failed
NR-58		100	90	76	52	36	28	15	8	NP	NP	NP	44	Passed	Passed	Passed	Passed
NR-59		100	83	59	43	27	21	19	13	NP	NP	NP	95	Passed	Passed	Passed	Passed
NR-60		100	85	67	42	29	23	17	7	NP	NP	NP	102	Passed	Passed	Passed	Passed

Table C1: Grading, CBR and Atterberg's limits of natural gravels in the Northern compared to Subbase specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Subbase Specifications			
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 14	LL≤ 30	CBR≥ 40
NR-61	100	83	62	48	40	29	21	11	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-62	100	88	68	41	27	22	18	11	NP	NP	NP	60	Passed	Passed	Passed	Passed
NR-63	100	89	55	33	25	22	18	11	NP	NP	NP	97	Passed	Passed	Passed	Passed

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Subbase specification			
	Gravel %	Sand %	Silt+Clay %	L.L. %	P.L %	P.L %		Grading	PI≤ 14	LL≤ 30	CBR≥ 40
NR-64	57	15	28	20	14	6	70	N/A	Passed	Passed	Passed
NR-65	81	7	12	20	15	5	49	N/A	Passed	Passed	Passed
NR-66	80	5	15	21	14	7	66	N/A	Passed	Passed	Passed
NR-67	76	5	19	29	19	10	27	N/A	Passed	Passed	Failed
NR-68	77	9	14	16	13	3	75	N/A	Passed	Passed	Passed

Table C2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 95% %	Subbase Specifications: Grading	PI≤ 14	LL≤ 30	CBR≥ 40
UWR-1		100	94	86	61	38	33		16	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 2		100	94	63	35	22	17		15	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 3		100	100	87	47	34	29		18	N/A	N/A	14	N/A	Passed	Passed	N/A	N/A
UWR- 4		100	83	69	48	27	22		10	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 5		100	87	61	37	30	23		11	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 6		100	98	88	60	39	32		12	N/A	N/A	9.1	N/A	Passed	Passed	N/A	N/A
UWR- 7		92	94	80	55	41	33		19	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
UWR- 8		100	97	90	69	41	36		11	N/A	N/A	7	N/A	Passed	Passed	N/A	N/A
UWR- 9		100	95	82	58	41	33		13	N/A	N/A	6	N/A	Passed	Passed	N/A	N/A
UWR -10		100	96	87	63	44	30		19	N/A	N/A	10	N/A	Passed	Passed	N/A	N/A
UWR -11		96	95	76	47	33	26		10	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR -12		100	100	81	52	36	34		8	N/A	N/A	6	N/A	Passed	Passed	N/A	N/A
UWR -13		81	76	57	40	31	29		9	N/A	N/A	4	N/A	Passed	Passed	N/A	N/A
UWR -14		100	96	87	56	36	29		13	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR -15		100	95	86	61	54	31		12	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR -16		100	100	93	70	54	42		19	N/A	N/A	5.7	N/A	Failed	Passed	N/A	N/A
UWR -17	100	90	82	77	55	36		20	8	20.6	13.1	7.5	45	Failed	Passed	Passed	Passed
UWR -18	100	99	97	90	65	35		22	13	34.6	20.5	14.1	73	Passed	Failed	Failed	Passed
UWR -19		100	99	94	70	48		28	13	21.2	17	4.2	47	Passed	Passed	Passed	Passed
UWR -20	100	83	86	76	50	29		20	8	23	18.5	4.5	60	Passed	Passed	Passed	Passed

Table C2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 95% %	Subbase Specifications: Grading	PI≤ 14	LL≤ 30	CBR≥ 40
UWR -21	100	86	65	48	31	21	14	7	26.5	17.1	9.4	50	Passed	Passed	Passed	Passed
UWR -22			100	87	55	43	25	13	18.8	14.1	4.7	56	Passed	Passed	Passed	Passed
UWR -23		100	59	97	80	49	25	8	21	14.5	6.5	80	Passed	Passed	Passed	Passed
UWR -24		100	55	89	63	37	21	10	21.8	16.6	5.2	40	Passed	Passed	Passed	Passed
UWR -25	100	100	95	82	63	38	31	19	26.1	16.9	9.2	38	Passed	Passed	Passed	Failed
UWR -26	100	99	90	73	62	45	26	12	20	14.1	5.9	45	Passed	Passed	Passed	Passed
UWR -27	100	98	86	61	40	23	15	6	17.6	12.7	4.9	60	Passed	Passed	Passed	Passed
UWR -28	100	95	82	69	49	30	21	7	19.1	14.1	5	60	Passed	Passed	Passed	Passed
UWR -29			100	94	70	41	26	13	26.2	14.3	11.9	45	Passed	Passed	Passed	Passed
UWR -30		100	98	82	51	32	26	18	27.3	15.3	12	55	Passed	Passed	Passed	Passed
UWR -31		100	100	97	82	61	36	19	24.7	15.7	9	45	Passed	Passed	Passed	Passed
UWR -32		100	98	89	65	43	29	11	23.1	17.2	5.9	70	Passed	Passed	Passed	Passed
UWR -33		100	98	85	58	37	28	13	20.5	12.6	7.9	60	Failed	Passed	Passed	Passed
UWR -34	100	95	94	71	44	33	23	11	20.9	15.3	5.6	70	Failed	Passed	Passed	Passed
UWR -35		100	99	95	79	43	29	13	17.6	11.9	5.7	78	Failed	Passed	Passed	Passed
UWR -36	100	99	83	72	55	39	29	15	22.4	15.2	7.2	67	Passed	Passed	Passed	Passed
UWR -37	100	99	91	72	57	40	31	19	28.7	16.9	11.8	45	Passed	Passed	Passed	Passed
UWR -38		100	98	82	67	43	37	26	21.5	16.5	5	55	Failed	Passed	Passed	Passed
UWR -39		100	95	83	62	42	30	22	23.6	18.5	5.1	55	Failed	Passed	Passed	Passed
UWR -40			88			46	24	13	NP	NP	NP	100	Passed	Passed	Passed	Passed

Table C2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 14	LL≤ 30	CBR≥ 40
UWR-41					52	33	17	24	19	5	30	Passed	Passed	Passed	Failed
UWR-42					35	25	16	23	19	4	95	Passed	Passed	Passed	Passed
UWR-43		98			34	17	13	26	25	1	42	Passed	Passed	Passed	Passed
UWR-44		97			39	25	18	24	19	4	23	Passed	Passed	Passed	Failed
UWR-45		100			43	27	17	24	20	4	50	Passed	Passed	Passed	Passed
UWR-46		83			21	15	14	32	22	10	73	Passed	Passed	Failed	Passed
UWR-47					40	23	18	32	16	16	18	Failed	Failed	Failed	Failed
UWR-48		100			39	23	11	32	16	16	67	Passed	Failed	Failed	Passed
UWR-49		78			42	32	16	21	15	6	48	Passed	Passed	Passed	Passed
UWR-50		96			46	28	19	34	19	15	67	Passed	Passed	Failed	Passed
UWR-51		82			39	26	15	26	17	9	42	Failed	Passed	Passed	Passed
UWR-52		89			21	15	13	29	19	10	70	Passed	Passed	Passed	Passed
UWR-53		94			39	29	8	23	19	4	50	Passed	Passed	Passed	Passed
UWR-54		95			42	32	29	18	16	2	28	Failed	Passed	Passed	Failed
UWR-55		100			68	49	30	27	19	8	37	Failed	Passed	Passed	Failed
UWR-56		99			56	35	18	20	19	1	53	Passed	Passed	Passed	Passed
UWR-57		83			21	16	6	NP	NP	NP	128	Passed	Passed	Passed	Passed

Table C3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	13.2 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 14	LL≤ 30	CBR≥ 40
UER-1	100	100	99	94	91	76	57		15	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-2	100	100	92	81	75	66	57		20	N/A	N/A	17	N/A	Failed	Failed	N/A	N/A
UER-3	100	100	98	95	94	85	72		19	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-4	93	93	90	88	84	75	66		22	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
UER-5	100	100	93	90	81	72	60		18	N/A	N/A	18	N/A	Failed	Failed	N/A	N/A
UER-6	100	100	95	95	94	82	58		21	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-7	100	100	97	89	81	70	61		16	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
UER-8	100	100	95	91	88	72	63		16	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-9	100	100	93	91	85	73	52		18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-10	100	100	94	90	88	80	75		19	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
UER-11			79				24	13	7	NP	NP	NP	120	Passed	Passed	Passed	Passed
UER-12			93				40	22	14	22	15	7	60	Failed	Passed	Passed	Passed
UER-13		100				58	36	23		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-14		100				70	52	34		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-15		100				57	32	19		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-16		100				63	36	21		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-17		100				44	27	15		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

Table C3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Subbase specifications

Sample Identification	Gradation: Gravel %	Sand %	Silt+ Clay %	Atterberg limits: L. L. %	P. I. %	P. I. %	CBR at 98%	Subbase specification: Grading	PI< 14	LL< 30	CBR> 40
UER-18	75	9	16	21	14	7	21	N/A	Passed	Passed	Failed
UER-19	61	21	18	21	14	7	33	N/A	Passed	Passed	Failed

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Table C4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI< 14	LL< 30	CBR≥ 40
AR-1	100	100	89	58	45	38	33	24	23	22	22	44	21	23	N/A	Passed	Failed	Failed	N/A
AR-2	100	100	82	56	46	43	33	27	21	19	18	35	19	15	N/A	Passed	Failed	Failed	N/A
AR-3	100	100	75	57	52	47	41	32	28	21	19	36	17	19	N/A	Passed	Failed	Failed	N/A
AR-4	100	100	78	58	47	37	31	21	17	15	14	33	17	16	N/A	Passed	Failed	Failed	N/A
AR-5	100	100	99	94	81	72	57	32	24	21	18	31	16	15	N/A	Passed	Failed	Failed	N/A
AR-6	100	100	98	91	80	65	54	37	33	28	15	37	20	17	N/A	Passed	Failed	Failed	N/A
AR-7	100	100	92	87	81	59	57	35	33	31	26	40	22	19	N/A	Failed	Failed	Failed	N/A
AR-8	-	-	-	-	-	-	-	-	-	-	-	44	20	24	N/A	N/A	Failed	Failed	N/A
AR-9	100	92	77	66	55	38	29	21	19	18	15	52	29	24	N/A	Failed	Failed	Failed	N/A
AR-10	100	100	100	98	89	64	48	28	24	21	15	52	25	26	N/A	Passed	Failed	Failed	N/A
AR-11	100	100	99	94	89	75	62	41	35	31	25	49	26	23	N/A	Failed	Failed	Failed	N/A
AR-12	100	100	100	72	60	48	36	24	20	14	11	24	14	9	N/A	Failed	Passed	Passed	N/A
AR-13	100	100	91	85	75	54	42	23	18	15	10	43	26	17	N/A	Passed	Failed	Failed	N/A
AR-14	100	100	97	90	84	73	61	38	33	30	28	53	25	28	N/A	Passed	Failed	Failed	N/A
AR-15	93	85	70	55	42	34	30	23	21	18	14	38	20	18	N/A	Failed	Failed	Failed	N/A
AR-16	100	97	90	86	79	74	70	57	42	29	23	46	22	24	N/A	Passed	Failed	Failed	N/A
AR-17	100	95	83	76	68	60	52	38	31	28	24	42	21	21	N/A	Failed	Failed	Failed	N/A
AR-18			92					35		24	21	28	17	11	35	Passed	Passed	Passed	Failed
AR-19			90					24		18	12	22	17	5	38	Passed	Passed	Passed	Failed
AR-20			92					18		12	9	25	18	7	98	Failed	Passed	Passed	Passed

Table C4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing							Atterberg Test			CBR at 98%	Subbase Specifications			
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI< 14	LL< 30	CBR≥ 40
AR-21		89			22	17	14	34	15	19	76	Failed	Failed	Failed	Passed
AR-22		92			45	21	18	36	22	12	35	Passed	Passed	Failed	Failed
AR-23		91			24	15	10	25	17	8	78	Passed	Passed	Passed	Passed
AR-24		94			30	28	16	24	16	8	56	Passed	Passed	Passed	Passed
AR-25		96			35	20	13	32	24	8	99	Passed	Passed	Failed	Passed
AR-26		98			36	20	10	27	15	12	60	Passed	Passed	Passed	Passed
AR-27		94			15	11	8	23	17	6	94	Failed	Passed	Passed	Passed
AR-28		91			12	7	5	23	16	7	138	Failed	Passed	Passed	Passed
AR-29		92			26	22	19	32	25	7	18	Passed	Passed	Failed	Failed
AR-30		93			37	27	23	49	20	29	40	Passed	Failed	Failed	Passed
AR-31		87			45	17	9	36	19	17	40	Failed	Failed	Failed	Passed
AR-32		89			36	25	19	39	22	16	50	Passed	Failed	Failed	Passed
AR-33		94			39	31	25	33	20	12	35	Passed	Passed	Failed	Failed
AR-34		79			26	19	14	42	19	23	35	Failed	Failed	Failed	Failed
AR-35		87			34	25	19	17	9	8	90	Failed	Passed	Passed	Passed
AR-36		95			42	25	16	28	16	12	100	Passed	Passed	Passed	Passed
AR-37		85			18	13	9	19	10	9	82	Passed	Passed	Passed	Passed
AR-38		84			22	16	11	18	9	9	68	Failed	Passed	Passed	Passed
AR-39		86			20	14	10	23	15	8	95	Failed	Passed	Passed	Passed
AR-40		72			30	23	20	43	23	20	35	Failed	Failed	Failed	Failed

Table C4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 75 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 14	LL< 30	CBR> 40
AR-41		69			30	25	21	37	21	16	40	Failed	Failed	Failed	Passed
AR-42		90			34	19	14	27	16	11	60	Failed	Passed	Passed	Passed
AR-43		71			31	24	21	36	19	17	47	Passed	Failed	Failed	Passed
AR-44		88			43	16	11	29	16	13	60	Failed	Passed	Passed	Passed
AR-45		89			27	19	13	20	11	9	65	Passed	Passed	Passed	Passed
AR-46		90			29	21	14	27	10	17	45	Passed	Failed	Passed	Passed
AR-47		90			38	29	19	23	12	11	80	Passed	Passed	Passed	Passed
AR-48		90			37	27	19	30	16	14	80	Passed	Passed	Passed	Passed
AR-49		90			34	22	14	23	11	12	87	Passed	Passed	Passed	Passed
AR-50		84			19	14	9	17	9	8	82	Passed	Failed	Passed	Passed
AR-51		90			36	29	21	39	23	16	40	Passed	Failed	Failed	Passed
AR-52		84			20	14	10	24	14	10	95	Passed	Passed	Passed	Passed
AR-53		86			20	15	11	24	14	10	100	Failed	Passed	Passed	Passed
AR-54		86			31	24	10	31	19	12	50	Failed	Passed	Failed	Passed
AR-55		96			26	21	16	39	20	19	60	Passed	Failed	Failed	Passed
AR-56		94			22	14	9	23	11	12	100	Passed	Passed	Passed	Passed
AR-57		87			25	17	11	21	10	11	82	Failed	Passed	Passed	Passed
AR-58		98			37	26	18	28	16	12	47	Passed	Passed	Passed	Passed
AR-59		84			19	14	9	19	10	9	73	Passed	Passed	Passed	Passed
AR-60		86			18	13	10	22	12	10	93	Failed	Passed	Passed	Passed

Table C4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 14	LL< 30	CBR≥ 40
AR-61				88			26	18	14	34	17	17	98	Failed	Failed	Failed	Passed
AR-62				91			28	17	9	23	11	12	52	Passed	Passed	Passed	Passed
AR-63				83			22	22	14	24	12	12	110	Passed	Passed	Passed	Passed
AR-64	100		100	100	95	75	56	40	27	38	18	20	75	Passed	Failed	Failed	Passed
AR-65	100		100	92	86	70	49	29	18	28	17	11	57	Failed	Passed	Passed	Passed
AR-66	100		100	91	81	61	46	29	17	30	18	12	50	Passed	Passed	Passed	Passed
AR-67				100			43	31	26	46	12	34	35	Passed	Failed	Failed	Failed

Sample Identification	Gradation: Gravel %	Sand %	Silt+Clay %	Atterberg Limits: L.L %	P.I %	P.I %	CBR at 98%	Subbase specification: Grading	PI< 14	LL< 30	CBR> 40
AR-68	81	10	9	N/A	N/A	N/A	59	N/A	N/A	N/A	Passed
AR-69	88	6	6	N/A	N/A	N/A	100	N/A	N/A	N/A	Passed
AR-70	52	16	32	N/A	N/A	N/A	42	N/A	N/A	N/A	Passed
AR-71	65	29	6	N/A	N/A	N/A	66	N/A	N/A	N/A	Passed
AR-72	56	24	20	N/A	N/A	N/A	95	N/A	N/A	N/A	Passed
AR-73	82	10	8	N/A	N/A	N/A	23	N/A	N/A	N/A	Failed
AR-74	59	20	21	N/A	N/A	N/A	96	N/A	N/A	N/A	Passed
AR-75	68	15	17	N/A	N/A	N/A	53	N/A	N/A	N/A	Passed

Table C5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 14	LL< 30	CBR≥ 40
WR-1	100	94.6	85	76.9	69	53	46.8	32.6	29.8	25.9	20.3	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
WR-2	100	100	79	63	47	38	29.7	25.9	23.1	20.4	16.3	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
WR-3	100	100	88	80.3	73	64	54.1	33.2	30.4	27.6	18.9	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
WR-4	93	90	79	73	62	55	48	41	38	35	13	N/A	N/A	4.5	N/A	Passed	Passed	N/A	N/A
WR-5	100	95	88	85	80	74	68	54	47	31	19	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
WR-6	97	95	81	73	67	59	51	39	33	24	17	N/A	N/A	12.4	N/A	Passed	Passed	N/A	N/A
WR-7	100	103	85	80.9	77	64	51.4	29.8	27.3	24.7	19.6	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
WR-8	100	103	86	77.3	69	62	55.8	46.9	39.5	32	20.2	N/A	N/A	14.4	N/A	Passed	Failed	N/A	N/A
WR-9	100	100	95	89.9	85	74	62.8	44	41.5	38.9	36.1	N/A	N/A	23	N/A	Failed	Failed	N/A	N/A
WR-10	100	100	95	88.8	82	62	49	33.6	29	27.4	21	N/A	N/A	8.4	N/A	Passed	Passed	N/A	N/A
WR-11	98.8	96.3	90	86.2	82	75	67.4	36.4	28.2	18.6	12.7	N/A	N/A	2.8	N/A	Passed	Passed	N/A	N/A
WR-12	100	72.8	61	52.7	44	30	25.1	20.4	15.8	12.8	7.9	N/A	N/A	13	N/A	Failed	Passed	N/A	N/A
WR-13	100	98.3	84	65.8	54	41	38	27.1	24.2	19.9	16	N/A	N/A	18.5	N/A	Passed	Failed	N/A	N/A
WR14	100	100	91	85	78	65	59.8	44.8	36.5	25.5	17.7	N/A	N/A	9.9	N/A	Passed	Passed	N/A	N/A
WR-15	97	91	85	77.4	67	58	47	31.6	28.4	21.7	16.7	N/A	N/A	8.5	N/A	Passed	Passed	N/A	N/A
WR-16	69.4	61.6	51	47	42	33	25.5	20	16.5	13.6	11	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
WR-17	100	97.5	96	90.4	83	68	55.5	37.3	31.2	28.7	22	N/A	N/A	13.5	N/A	Passed	Passed	N/A	N/A
WR-18	96.3	94.7	92	87.1	81	69	58.2	39.1	33	27.8	14.8	N/A	N/A	8.6	N/A	Passed	Passed	N/A	N/A
WR-19	96.2	93.3	88	79.9	72	53	44.4	32.9	30.1	28.5	18.1	N/A	N/A	7.5	N/A	Passed	Passed	N/A	N/A
WR-20	100	100	83		53		36	30		27	23	26	16	10	88	Failed	Passed	Passed	Passed

Table C5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 14	LL< 30	CBR≥ 40
WR-21	100	100	84	53	37	31	27	22	33	18	15	68	Failed	Failed	Failed	Passed
WR-22	100	100	71	55	44	38	31	26	31	17	14	68	Failed	Passed	Failed	Passed
WR-23	100	100	89	66	45	38	34	28	30	21	9	68	Failed	Passed	Passed	Passed
WR-24	100	92	66	39	27	23	21	20	29	16	13	82	Failed	Passed	Passed	Passed
WR-25	100	100	88	74	36	24	21	18	35	20	15	80	Failed	Failed	Failed	Passed
WR-26	100	100	92	67	34	28	20	17	36	25	11	80	Failed	Passed	Failed	Passed
WR-27	100	100	85	63	42	35	31	27	34	22	12	82	Failed	Passed	Failed	Passed
WR-28	100	100	82	58	38	31	28	25	37	24	13	60	Failed	Passed	Failed	Passed
WR-29	100	100	87	68	53	45	40	33	28	14	14	56	Failed	Passed	Passed	Passed
WR-30	100	100	86	62	33	26	24	21	33	23	10	59	Failed	Passed	Failed	Passed
WR-31	100	100	89	73	43	34	32	30	41	29	12	52	Failed	Passed	Failed	Passed
WR-32	100	100	83	71	57	50	47	44	42	23	19	58	Failed	Failed	Failed	Passed
WR-33	100	100	72	43	29	24	21	18	29	16	13	79	Failed	Passed	Passed	Passed
WR-34	100	100	83	48	31	24	19	14	20	15	5	180	Failed	Passed	Passed	Passed
WR-35	100	100	83	62	44	37	32	28	31	18	13	72	Failed	Passed	Failed	Passed
WR-36	100	100	84	58	31	22	19	17	32	19	13	102	Failed	Passed	Failed	Passed
WR-37		100	100	87	45	30	25	21	35	20	15	45	Failed	Failed	Failed	Passed
WR-38		100	98	82	50	36	32	27	42	24	17	42	Failed	Failed	Failed	Passed
WR-39		100	94	75	52	42	38	30	39	25	14	40	Failed	Passed	Failed	Passed
WR-40		100	96	85	61	43	37	31	39	24	15	32	Failed	Failed	Failed	Failed

Table C5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test LL %	PL %	PI %	CBR at 98% %	Subbase Specifications Grading	PI≤ 14	LL< 30	CBR≥ 40
WR-41	100	99	90	57	45	37	30	38	25	13	22	Failed	Passed	Failed	Failed
WR-42	100	91	70	51	42	36	25	34	24	10	48	Failed	Passed	Failed	Passed
WR-43	97	96	86	48	37	32	24	34	23	11	54	Failed	Passed	Failed	Passed
WR-44	98	97	85	53	40	35	31	44	26	18	86	Failed	Failed	Failed	Passed
WR-45	100	93	75	49	40	37	35	58	35	24	64	Failed	Failed	Failed	Passed
WR-46	100	91	66	40	28	29	26	50	32	18	55	Failed	Passed	Failed	Passed
WR-47	100	94	72	45	38	34	26	40	25	15	59	Failed	Failed	Failed	Passed
WR-48	100	89	69	42	31	27	23	39	25	14	88	Failed	Passed	Failed	Passed
WR-49	100	92	67	45	34	27	25	43	28	16	95	Failed	Failed	Failed	Passed
WR-50					30	27	19	40	25	15	30	Failed	Failed	Failed	Failed
WR-51					34	27	16	28	19	9	48	Failed	Passed	Passed	Passed
WR-52					27	22	22	39	32	7	23	Failed	Passed	Failed	Failed
WR-53					34	26	14	34	21	14	36	Failed	Passed	Failed	Failed
WR-54					22	17	13	25	17	8	48	Failed	Passed	Passed	Passed
WR-55					20	14	11	38	22	15	16	Failed	Failed	Failed	Failed
WR-56					37	29	18	24	16	8	56	Failed	Passed	Passed	Passed
WR-57					26	22	18	21	14	7	31	Failed	Passed	Passed	Failed
WR-58					24	19	14	30	19	12	22	Failed	Passed	Passed	Failed
WR-59					45	38	32	45	23	22	14	Failed	Failed	Failed	Failed
WR-60					33	24	19	35	23	12	44	Failed	Passed	Failed	Passed

Table C5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test LL %	PL %	PI %	CBR at 98% %	Subbase Specifications Grading	PI≤ 14	LL≤ 34	CBR≥ 40
WR-61					24	18	15	35	19	16	37	Passed	Failed	Failed	Failed
WR-62					32	16	12	30	20	10	40	Passed	Passed	Passed	Passed
WR-63					29	23	20	44	26	18	28	Passed	Failed	Failed	Failed
WR-64					38	32	28	44	30	14	16	Failed	Passed	Failed	Failed
WR-65					31	26	22	43	29	14	34	Passed	Passed	Failed	Failed
WR-66					26	18	11	23	18	5	55	Passed	Passed	Passed	Passed
WR-67					29	22	18	36	21	15	34	Passed	Failed	Failed	Failed
WR-68					44	38	28	39	23	16	17	Failed	Failed	Failed	Failed
WR-69					34	29	23	40	30	11	48	Failed	Passed	Failed	Passed
WR-70					33	26	16	23	13	10	59	Passed	Passed	Passed	Passed
WR-71					40	33	24	37	20	18	13	Failed	Failed	Failed	Failed
WR-72					22	16	12	32	19	13	31	Passed	Passed	Failed	Failed

Table C6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			CBR at 98%	Subbase Specifications			
	37.5	20	13.2	10	6.7	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 14	LL≤ 30	CBR≥ 40
BAR-1	100	95	91.6	88	84	69.6	41.1	40.3	39.2	30	N/A	N/A	1.2	N/A	Failed	Passed	N/A	N/A
BAR-2	100	93	88.5	86	76	65.9	47.9	41.3	37.5	30	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-3	100	84	72.9	65	51	45	36.4	32.9	30.8	26.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-4	100	99	93.7	87	67	50.4	29.7	29.3	25.6	17	N/A	N/A	NP	N/A	Passed	Passed	N/A	N/A
BAR-5	100	97	93.9	85	63	45.4	21.5	17.3	16.3	10.2	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
BAR-6	100	100	100	98	90	74.7	37.2	28.2	24.9	12.6	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-7	100	95	80.3	72	58	48.2	41.3	38.2	36.2	18.3	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-8	100	74	58.6	54	47	43.7	39.4	37.8	33.4	14.6	N/A	N/A	NP	N/A	Passed	Passed	N/A	N/A
BAR-9	100	97	92.7	88	75	62	34.9	28.2	23.6	14.5	N/A	N/A	10.2	N/A	Passed	Passed	N/A	N/A
BAR-10	100	90	79.2	74	55	39	13	9.5	7.7	5.3	N/A	N/A	2.4	N/A	Failed	Passed	N/A	N/A
BAR-11	100	90	68	54	41	37.3	34.3	31.9	25.3	11	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-12	95.6	89	83.4	77	67	55.8	35.2	27.2	21	15.6	N/A	N/A	16.2	N/A	Failed	Failed	N/A	N/A
BAR-13	100	93	92.1	91	77	63.3	34.6	26.4	22.9	19.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-14	100	87	77	66	51	35.9	18.3	14.9	13.1	10.9	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-15	100	97	92	88	76	63.8	50.1	46.9	43	29.8	N/A	N/A	15	N/A	Failed	Failed	N/A	N/A
BAR-16	100	99	92	84	70	55.3	52	51.2	45.1	28.6	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
BAR-17							27		19	16	33	17	15	60	Passed	Failed	Failed	Passed
BAR-18							22		14	19	19	14	5	63	Passed	Passed	Passed	Passed
BAR-19							37		27	23	35	16	19	N/A	Failed	Failed	Failed	N/A
BAR-20							28		21	18	45	25	20	36	Failed	Failed	Failed	Failed

Table C6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Subbase specifications

Sample Identification	Gradation			Atterberg Limits			CBR at 98%	Subbase specification			
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. L %	P. I %		Grading	PI≤ 14	LL≤30	CBR≥ 40
BAR-21	75	11	14	18	14	4	44	N/A	Passed	Passed	Passed
BAR-22	88	12	0	23	18	5	83	N/A	Passed	Passed	Passed
BAR-23	70	19	11	15	12	3	46	N/A	Passed	Passed	Passed

Table C7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	75	53	37.5	20	10	4.75	2.36	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI< 14	LL≤ 30	CBR> 40
ER-1	100		91.7	50	38	26.9	19.7	15.9	10.7	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-2	100		85.7	50	37	26.5	19.5	15.75	12.3	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-3	100		95.1	85	77	58	43.5	22.3	11	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-4	98		91.4	76	63	52.5	46.2	28.2	21.4	N/A	N/A	16.3	N/A	Passed	Failed	N/A	N/A
ER-5	97		86.1	76	66	53.5	47.6	31.4	25.9	N/A	N/A	13.3	N/A	Failed	Passed	N/A	N/A
ER-6	100		93	78	64	53.4	46.6	28.9	23.9	N/A	N/A	19.7	N/A	Failed	Failed	N/A	N/A
ER-7	98		88.8	72	58	48.7	42.5	25.2	19.4	N/A	N/A	19.6	N/A	Failed	Failed	N/A	N/A
ER-8	100		100	100	76	56.1	40.5	31.3	22.1	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-9	100		100	100	88	70	42	34	30	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-10	100		100	100	99	72	52	19	12	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-11			95	86	60	50	41	26	18	25	18	7	91	Passed	Passed	Passed	Passed
ER-12			98	94	86	69	35	18	9	21	15	6	134	Failed	Passed	Passed	Passed
ER-13			92	88	76	60	43	26	16	25	14	11	73	Failed	Passed	Passed	Passed
ER-14			95	83	67	45	27	17	10	23	17	6	99	Failed	Passed	Passed	Passed
ER-15			94	80	64	45	29	15	7	26	15	11	135	Failed	Passed	Passed	Passed
ER-16			95	85	72	57	42	21	9	23	11	12	67	Failed	Passed	Passed	Passed
ER-17	100	99		96	81	54	38	30	15	45	23	22	38	Passed	Failed	Failed	Failed
ER-18	100	100		100	87	57	38	30	15	47	23	24	N/A	Passed	Failed	Failed	N/A
ER-19	100	100		98	86	55	37	28	12	43	22	21	N/A	Passed	Failed	Failed	N/A
ER-20	100	95	86	68	45	37	31	25	13	28	16	12	40	Failed	Passed	Passed	Passed

Table C7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			CBR at 98%	Subbase Specifications			
	75	53	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI< 14	LL≤ 30	CBR> 40
ER-21	99	97	93	80	65	54	45	38	33	15	19	13	6	21	Passed	Passed	Passed	Failed
ER-22	98	94	88	72	61	50	42	38	31	16	25	15	10	45	Failed	Passed	Passed	Passed
ER-23	100	99	95	80	61	49	38	35	34	26	40	21	19	21	Failed	Failed	Failed	Failed
ER-24	100	99	96	81	61	46	35	29	22	14	37	21	16	35	Passed	Failed	Failed	Failed

Table C8: Grading and plastic limits of natural gravels in the Central Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Subbase Specifications			
	53	37.5	20	13.2	10	6.7	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 14	LL≤ 30	CBR≥ 40
CR-1		100	92	85	78	62	49	26	19	16	13	43.5	26.8	16.7	N/A	Passed	Failed	Failed	N/A
CR-2		100	89	81	74	62	55	41	33	23	15	25.9	15.7	10.2	N/A	Passed	Passed	Passed	N/A
CR-3		100	88	83	77	61	49	31	25	22	18	42.8	29.8	13	N/A	Passed	Passed	Failed	N/A
CR-4		100	89	82	76	65	57	44	40	28	17	22.8	15.4	7.4	N/A	Passed	Passed	Passed	N/A
CR-5		100	77	64	54	42	36	28	24	21	17	33.5	20.2	13.3	N/A	Passed	Passed	Failed	N/A
CR-6		100	92	82	75	64	55	35	26	21	16	33.7	21.7	12	N/A	Passed	Passed	Failed	N/A
CR-7		100	87	82	76	66	60	41	30	20	13	24.7	15.9	8.8	N/A	Passed	Passed	Passed	N/A
CR-8		100	78	69	62	52	47	38	33	29	23	32.1	20	12.1	N/A	Failed	Passed	Failed	N/A
CR-9		100	85	76	68	57	49	35	28	21	14	31.5	18.7	12.8	N/A	Passed	Passed	Failed	N/A
CR-10		100	91	90	78	68	62	48	38	31	23	38.5	20	18.9	N/A	Failed	Failed	Failed	N/A
CR-11		100	94	90	87	78	71	49	38	28	20	30.7	18.4	12.3	N/A	Passed	Passed	Failed	N/A
CR-12		100	92	90	86	78	72	60	51	41	24	38.9	22	16.9	N/A	Failed	Failed	Failed	N/A
CR-13	100	100	90		61		31	24		17	13	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
CR-14	100	100	97		72		50	37		29	24	N/A	N/A	15	N/A	Failed	Failed	N/A	N/A
CR-15	100	95	74		48		33	25		18	14	N/A	N/A	14	N/A	Failed	Passed	N/A	N/A
CR-16	100	100	91		75		49	34		15	9	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
CR-17	100	100	87		78		53	38		16	7	N/A	N/A	4	N/A	Passed	Passed	N/A	N/A
CR-18	100	97	92		83		62	34		13	9	N/A	N/A	7	N/A	Passed	Passed	N/A	N/A
CR-19	100	100	96		87		67	44		21	15	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
CR-20	100	100	89		70		53	41		29.5	18	N/A	N/A	8.6	N/A	Passed	Passed	N/A	N/A

Table C8: Grading and plastic limits of natural gravels in the Central Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	75	53	37.5	20	10	4.75	2.36	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 14	LL≤ 30	CBR≥ 40
CR-21		100	98	81	64	50	36	18	17	N/A	N/A	14	N/A	Passed	Passed	N/A	N/A
CR-22		100	98	86	76	58	45	25	24	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
CR-23		100	100	100	93	79	40	17.5	11.5	N/A	N/A	11.8	N/A	Failed	Passed	N/A	N/A
CR-24		100	100	100	89	66	54	37.75	21.5	N/A	N/A	19.1	N/A	Failed	Failed	N/A	N/A
CR-25		100	100	100	81	58	39	22.9	17	N/A	N/A	12.9	N/A	Passed	Passed	N/A	N/A
CR-26		100	100	94	88	72	52	31.5	8.5	N/A	N/A	4.2	N/A	Passed	Passed	N/A	N/A
CR-27	100		95	91	84	69	43	21	11	23	12	11	106	Passed	Passed	Passed	Passed
CR-28	99		95	90	83	70	40	22	15	35	17	19	60	Passed	Failed	Failed	Passed
CR-29	100		96	91	81	69	43	22	15	29	14	15	90	Passed	Passed	Passed	Passed
CR-30	98		93	91	83	67	40	20	9	23	10	13	63	Passed	Passed	Passed	Passed
CR-31	99		96	94	86	65	35	20	10	25	11	14	67	Passed	Passed	Passed	Passed
CR-32	100		95	89	78	73	39	22	9	20	10	10	237	Passed	Passed	Passed	Passed
CR-33	100		99	97	90	76	42	21	12	27	12	15	99	Failed	Failed	Passed	Passed
CR-34	100		97	94	85	62	27	14	5	11	5	6	139	Passed	Passed	Passed	Passed
CR-35	100		98	95	83	62	38	19	9	17	9	8	101	Passed	Passed	Passed	Passed
CR-36	100		97	93	88	73	44	26	12	10	5	5	129	Passed	Passed	Passed	Passed
CR-37	99		95	86	76	57	32	20	10	34	13	21	72	Passed	Failed	Failed	Passed
CR-38	99		93	87	78	52	44	36	25	61	24	37	10	Failed	Failed	Failed	Failed
CR-39	100	100	97	91	85	70	30	12	7	28	14	14	42	Passed	Passed	Passed	Passed
CR-40	100		97	92	82	64	46	37	35	65	29	36	14	Failed	Failed	Failed	Failed

Table C8: Grading and plastic limits of natural gravels in the Central Region compared to Subbase Specifications

Sample Identification	Grading											Atterberg Test			CBR at 95%	Subbase Specifications			
	Percentage Passing																		
	75 mm	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 14	LL≤ 30	CBR≥ 40
CR-41	100		93	89	82		67	47		24	20	28	12	16	113	Passed	Failed	Passed	Failed
CR-42	100	99	97	93	88		68	48	40	38	30	43	23	20	34	Failed	Failed	Failed	Failed
CR-43	100	100	96	85	70		57	38	34	30	21	35	17	18	36	Passed	Failed	Failed	Failed
CR-44	100	100	98	94	87		66	34	31	30	20	53	28	25	47	Failed	Failed	Failed	Passed
CR-45	100	100	98	92	64		46	45	36	34	25	42	21	19	15	Failed	Failed	Failed	Failed
CR-46	100	96	91	78	47		36	32	30	28	18	30	16	14	20	Passed	Passed	Failed	Failed
CR-47	100	100	92	84	56		38	26	23	22	20	62	27	35	26	Passed	Failed	Failed	Failed
CR-48	100	100	98	92	80		56	34	28	27	22	37	23	14	28	Passed	Passed	Failed	Failed
CR-49	100	100	96	85	62		46	39	37	33	26	44	21	23	38	Failed	Failed	Failed	Failed
CR-50	100	84	80	70	53		45	33	29	28	23	43	27	16	27	Failed	Failed	Failed	Failed
CR-51	100	100	96	86	66		46	31	23	20	15	42	23	19	20	Passed	Failed	Failed	Failed
CR-52	100	83	80	67	55		42	33	29	27	20	41	21	20	23	Failed	Failed	Failed	Failed
CR-53	100	99	96	88	68		40	21	13	8	1	36	19	16	24	Failed	Failed	Failed	Failed
CR-54	100	100	94	84	69		51	37	27	27	11	54	13	11	51	Passed	Passed	Failed	Passed
CR-55		100	98	90	69	59	50	33	24	16	5	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
CR-56		100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

Table C9: Grading and plastic limits of natural gravels in the Volta Region compared to Subbase specifications

Sample Identification	Grading									Atterberg Test			CBR at 95%	Subbase Specifications			
	Percentage Passing																
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤14	LL≤ 30	CBR≥ 40
VR-1	100	98	85		58	44		25	14	N/A	N/A	8.8	N/A	Passed	Passed	N/A	N/A
VR-2	100	96	61		29	19		11	9	N/A	N/A	8.8	N/A	Failed	Passed	N/A	N/A
VR-3	100	92	74		52	41		26	14	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
VR-4	100	100	93		64	56		28	22	N/A	N/A	14.7	N/A	Failed	Failed	N/A	N/A
VR-5	100	100	65		44	25		17	10	N/A	N/A	6.1	N/A	Failed	Passed	N/A	N/A
VR-6	100	100	72		52	38		21	13	N/A	N/A	4.3	N/A	Failed	Passed	N/A	N/A
VR-7	100	100	93		76	79		52	13	N/A	N/A	4.3	N/A	Failed	Passed	N/A	N/A
VR-8	100	100	70		52.5	36		23	18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
VR-9	100	100	87		61	43		28	22	N/A	N/A	7.7	N/A	Passed	Passed	N/A	N/A
VR-10	100	96	84		69	51		29	16	N/A	N/A	6.2	N/A	Passed	Passed	N/A	N/A
VR-11	100	91	78		57	53		26	14	N/A	N/A	7.4	N/A	Passed	Passed	N/A	N/A
VR-12		99	98	63	29	24	22		14	39	22	17	50	Failed	Failed	Failed	Passed
VR-13			100	69	33	26	23		14	43	24	21	45	Passed	Failed	Failed	Passed
VR-14		100	99	71	38	20	17		8	40	25	15	55	Failed	Failed	Failed	Passed
VR-15			100	81	44	25	17		14	33	18	15	64	Passed	Failed	Failed	Passed
VR-16		100	98	86	47	24	20		12	28	17	11	60	Passed	Passed	Passed	Passed
VR-17		100	97	87	56	38	32		18	23	15	8	50	Passed	Passed	Passed	Passed
VR-18		100	98	86	57	3	33		14	21	14	7	70	Failed	Passed	Passed	Passed
VR-19		100	97	86	34	17	12		4	25	19	6	50	Failed	Passed	Passed	Passed
VR-20		100		73	36	16	12		6	28	18	10	57	Failed	Passed	Passed	Passed

Table C9: Grading and plastic limits of natural gravels in the Volta Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 14	LL≤ 30	CBR≥ 40
VR-21	100		87	72	46	32	26		12	33	16	17	43	Passed	Failed	Failed	Passed
VR-22		100	99	77	48	32	27		18	46	26	20	45	Passed	Failed	Failed	Passed
VR-23			100	69	33	23	20		13	38	22	16	50	Passed	Failed	Failed	Passed
VR-24		99	98	63	29	21	17		12	39	21	18	40	Passed	Failed	Failed	Passed
VR-25			93			41		35	25	23	13	10	76	Failed	Passed	Passed	Passed
VR-26			100			43		27	7	21	20	1	168	Passed	Passed	Passed	Passed
VR-27			100			51		32	20	20	14	6	98	Passed	Passed	Passed	Passed
VR-28			100			43		34	23	23	17	6	66	Failed	Passed	Passed	Passed
VR-29			100			28		23	15	19	15	4	94	Passed	Passed	Passed	Passed
VR-30			99			33		26	21	20	14	6	96	Passed	Passed	Passed	Passed
VR-31			99			40		28	22	28	20	8	148	Passed	Passed	Passed	Passed
VR-32			99			36		25	20	27	20	7	98	Passed	Passed	Passed	Passed
VR-33			99			43		28	19	17	14	3	88	Passed	Passed	Passed	Passed
VR-34			99			37		33	24	19	13	6	90	Failed	Passed	Passed	Passed
VR-35			99			31		25	21	21	14	7	82	Passed	Passed	Passed	Passed
VR-36			99			27		22	16	20	4	16	81	Passed	Failed	Passed	Passed
VR-37			100			29		25	19	19	16	3	130	Passed	Passed	Passed	Passed
VR-38			100			49		31	21	19	16	3	53	Passed	Passed	Passed	Passed
VR-39			59			42		37	25	20	15	5	100	Failed	Passed	Passed	Passed

Table C10: Grading and plastic limits of natural gravels in the Greater Accra Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 14	LL≤ 30	CBR≥ 40
GAR-1	100		98	79		59	41	33	27	18	22	12	10	80	Passed	Passed	Passed	Passed
GAR-2	100		100	91		62	39	31	25	14	20	14	b	N/A	Failed	Passed	Failed	N/A
GAR-3	100		100	81		57	37	32	28	16	19	12	7	N/A	Failed	Passed	Passed	N/A
GAR-4	100		98	70		54	46	43	38	22	18	11	7	50	Failed	Passed	Passed	Passed
GAR-5	100		99	97		81	52	41	33	20	29	16	13	22	Failed	Passed	Failed	Failed
GAR-6	100		100	96		68	41	33	26	16	23	12	11	N/A	Failed	Passed	Passed	N/A
GAR-7	100		100	93		72	39	28	21	14	24	13	11	N/A	Failed	Passed	Passed	N/A
GAR-8	100		100	95		77	48	37	31	19	24	11	13	N/A	Failed	Passed	Passed	N/A
GAR-9	100		98	83		58	43	39	33	17	22	9	13	50	Passed	Passed	Passed	Passed
GAR-10	100		100	89		70	37	27	19	11	20	10	10	N/A	Passed	Passed	Passed	N/A
GAR-11	99		91	77		58	36	29	22	14	28	15	13	50	Passed	Passed	Passed	Passed
GAR-12	100		98	92		73	48	33	26	17	22	12	10	N/A	Failed	Passed	Passed	N/A
GAR-13	100		95	87		68	42	30	24	15	24	13	11	N/A	Passed	Passed	Passed	N/A
GAR-14	100		96	80		59	38	32	24	15	19	11	8	N/A	Passed	Passed	Passed	N/A
GAR-15	100		97	87		67	38	28	21	12	24	14	10	70	Passed	Passed	Passed	Passed
GAR-16		96	85	67	53	46	34	24	15	8	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-17	100	98	92	68	51	44	34	30	25	15	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-18			100	96	83	74	52	42	33	19	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
GAR-19	100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-20	100	97	87	69	54	45	35	31	23	12	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-21		97	92	83		68	41		17	9	19	15	4	N/A	Passed	Passed	Passed	N/A

APPENDIX D

COMPARING GRADING, CBR AND ATTERBERG LIMITS OF NATURAL GRAVELS WITH MOT G80 BASE REQUIREMENTS

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Table D1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
NR-1	100	90	83	69	59	34	23	17	11	21.7	13.3	8.4	N/A	Failed	Passed	Passed	N/A
NR-2	100	93	87	68	49	23	15	13	11	24.3	15.7	8.6	N/A	Failed	Passed	Passed	N/A
NR-3	100	92	86	66	46	20	14	12	10	21.8	13.6	8.2	N/A	Failed	Passed	Passed	N/A
NR-4	100	91	82	63	51	30	23	20	17	22.6	15.1	7.5	N/A	Failed	Passed	Passed	N/A
NR-5	100	89	76	55	45	32	28	27	25	27.2	15.4	11.8	N/A	Failed	Failed	Failed	N/A
NR-6	100	98	91	77	65	44	34	29	23	26.3	15.4	10.9	N/A	Failed	Failed	Failed	N/A
NR-7	100	100	96	80	59	26	20	18	13	19.6	13.2	6.4	N/A	Failed	Passed	Passed	N/A
NR-8	100	97	90	77	64	33	21	17	14	33.5	20.7	12.8	N/A	Failed	Failed	Failed	N/A
NR-9	100		78		41.1	22.3	14.6	12.4	10.4	N/A	N/A	12	N/A	Failed	Failed	N/A	N/A
NR-10	100		95		58.5	33.8	23.9	20.2	16.8	N/A	N/A	11.1	N/A	Failed	Failed	N/A	N/A
NR-11	100		92		57.7	30.2	19.5	16.7	13	N/A	N/A	18.3	N/A	Failed	Failed	N/A	N/A
NR-12	100		90		63.7	46.8	42	38.8	25.6	N/A	N/A	17.3	N/A	Failed	Failed	N/A	N/A
NR-13	100		96		70.6	34.2	25.6	23.2	15.5	N/A	N/A	23.7	N/A	Failed	Failed	N/A	N/A
NR-14	100		87		53.6	27.2	17.7	13.9	9	N/A	N/A	13.3	N/A	Failed	Failed	N/A	N/A
NR-15	100		83		53.2	33	27.5	25.5	22.6	N/A	N/A	14.3	N/A	Failed	Failed	N/A	N/A
NR-16	100		99.5		88.4	46	34.2	31.5	14.4	N/A	N/A	12.3	N/A	Failed	Failed	N/A	N/A
NR-17	100		94		56.9	34.4	26.8	24	13.9	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
NR-18	100		97		70.9	33.6	24.8	23.4	19.4	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
NR-19	100		64		29.7	17.7	14	13	10.9	N/A	N/A	14.5	N/A	Failed	Failed	N/A	N/A
NR-20	100		99		93	63.2	47.2	38.1	33	N/A	N/A	16.1	N/A	Failed	Failed	N/A	N/A

Table D1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
NR-21		100	100	85	47	24	18	16	12	N/A	N/A	16.4	N/A	Failed	Failed	N/A	N/A
NR-22		100	100	99	73	38	29	26	20	N/A	N/A	14	N/A	Failed	Failed	N/A	N/A
NR-23		100	100	97	73	39	30	28	19	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
NR-24		100	100	90	56	31	30	30	21	N/A	N/A	7.7	N/A	Failed	Passed	N/A	N/A
NR-25		100	100	97	57	33	27	26	19	N/A	N/A	3.9	N/A	Failed	Passed	N/A	N/A
NR-26		100	100	66	43	30	26	24	19	N/A	N/A	10.3	N/A	Failed	Failed	N/A	N/A
NR-27		100	100	94	56	31	25	24	17	N/A	N/A	14.1	N/A	Failed	Failed	N/A	N/A
NR-28	100	92	83	64	46	34		30	19	17.2	12.3	4.9	85	Failed	Passed	Passed	Passed
NR-29	100	91	78	53	36	31		29	14	17.8	12.3	5.5	75	Failed	Passed	Passed	Failed
NR-30		100	82	60	45	37		32	14	14.8	10.1	4.7	56	Failed	Passed	Passed	Failed
NR-31	100	98	84	63	42	30		26	13	17.8	10.6	7.2	80	Failed	Passed	Passed	Passed
NR-32	100	97	91	84	76	45		38	20	17.4	12.8	4.6	42	Failed	Passed	Passed	Failed
NR-33	100	95	92	79	50	32		20	6	17.4	12.7	4.7	45	Failed	Passed	Passed	Failed
NR-34	100	95	91	80	48	25		18	7	18.2	12.5	5.7	55	Failed	Passed	Passed	Failed
NR-35	100	96	90	78	60	40		32	23	17	13.5	3.5	32	Failed	Passed	Passed	Failed
NR-36		100	95	81	50	29		25	12	NP	NP	NP	35	Failed	Passed	Passed	Failed
NR-37	100	96	79	48	46	27		19	7	26.6	18	8.6	55	Passed	Passed	Failed	Failed
NR-38		100	91	84	64	45		36	14	21.2	14.7	6.5	50	Failed	Passed	Passed	Failed
NR-39	100	89	78	54	38	25		20	15	24.6	18.8	5.8	51	Passed	Passed	Passed	Failed
NR-40	100	96	89	68	40	25		11	5	22.2	17.2	5	65	Failed	Passed	Passed	Failed

Table D1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
NR-41	100	97	92	86	57	33		25	19	21.8	14.9	6.9	23	Failed	Passed	Passed	Failed
NR-42	100	95	83	72	54	29		21	17	23.8	18.2	5.6	20	Failed	Passed	Passed	Failed
NR-43	100	95	89	76	60	43		29	13	19.8	13.8	6	33	Failed	Passed	Passed	Failed
NR-44		100	93	80	75	48		34	11	19.4	13.9	5.5	46	Failed	Passed	Passed	Failed
NR-45	100	97	92	80	59	37		22	9	17.8	13.4	4.4	60	Failed	Passed	Passed	Failed
NR-46		100	85	65	42	31	24	17	7	19	14	5	95	Passed	Passed	Passed	Passed
NR-47		100	90	70	41	24	20	18	14	18	13	5	69	Failed	Passed	Passed	Failed
NR-48		100	95	75	66	43	41	39	32	57	25	31	50	Failed	Failed	Failed	Failed
NR-49		100	91	70	40	20	14	15	10	19	13	6	90	Failed	Passed	Passed	Passed
NR-50		100	89	74	49	29	23	21	11	NP	NP	NP	50	Failed	Passed	Passed	Failed
NR-51		100	94	70	31	16	13	9	3	NP	NP	NP	50	Failed	Passed	Passed	Failed
NR-52		100	98	79	49	24	23	14	9	NP	NP	NP	118	Failed	Passed	Passed	Passed
NR-53		100	99	84	41	22	18	12	5	NP	NP	NP	125	Failed	Passed	Passed	Passed
NR-54		100	100	90	56	36	29	20	11	NP	NP	NP	N/A	Failed	Passed	Passed	N/A
NR-55		100	100	89	57	33	27	19	7	NP	NP	NP	N/A	Failed	Passed	Passed	N/A
NR-56		100	100	88	45	24	20	14	7	NP	NP	NP	200	Failed	Passed	Passed	Passed
NR-57		100	94	69	37	33	28	16	5	NP	NP	NP	32	Failed	Passed	Passed	Failed
NR-58		100	90	76	52	36	28	15	8	NP	NP	NP	44	Failed	Passed	Passed	Failed
NR-59		100	83	59	43	27	21	19	13	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-60		100	85	67	42	29	23	17	7	NP	NP	NP	102	Passed	Passed	Passed	Passed

Table D1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Base Specifications			
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
NR-61	100	83	62	48	40	29	21	11	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-62	100	88	68	41	27	22	18	11	NP	NP	NP	60	Passed	Passed	Passed	Failed
NR-63	100	89	55	33	25	22	18	11	NP	NP	NP	97	Passed	Passed	Passed	Passed

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Base specification			
	Gravel %	Sand %	Silt+Clay %	L.L. %	P.I. %	P.I. %		Grading	PI< 10	LL< 25	CBR> 80
NR-64	57	15	28	20	14	6	70	N/A	Passed	Passed	Failed
NR-65	51	7	12	20	15	5	49	N/A	Passed	Passed	Failed
NR-66	80	5	15	21	14	7	66	N/A	Passed	Passed	Failed
NR-67	76	5	19	29	19	10	27	N/A	Passed	Failed	Failed
NR-68	77	9	14	16	13	3	75	N/A	Passed	Passed	Failed

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Table D2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Base specifications

Sample Identification	Grading (Percentage Passing)									Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
UWR-1		100	94	86	61	38	33		16	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 2		100	94	63	35	22	17		15	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 3		100	100	87	47	34	29		18	N/A	N/A	14	N/A	Failed	Failed	N/A	N/A
UWR- 4		100	89	69	41	27	22		10	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UWR- 5		100	87	61	37	30	23		11	N/A	N/A	8	N/A	Failed	Passed	N/A	N/A
UWR- 6		100	98	88	60	39	32		12	N/A	N/A	9.1	N/A	Failed	Passed	N/A	N/A
UWR- 7		92	94	80	55	41	33		19	N/A	N/A	12	N/A	Failed	Failed	N/A	N/A
UWR- 8		100	97	90	69	41	36		11	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
UWR- 9		100	95	82	58	41	33		13	N/A	N/A	6	N/A	Failed	Passed	N/A	N/A
UWR -10		100	96	87	63	44	39		19	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UWR -11		96	95	76	47	33	26		10	N/A	N/A	8	N/A	Failed	Passed	N/A	N/A
UWR -12		100	100	81	52	36	34		8	N/A	N/A	6	N/A	Failed	Passed	N/A	N/A
UWR -13		81	76	57	40	31	29		9	N/A	N/A	4	N/A	Failed	Passed	N/A	N/A
UWR -14		100	96	87	56	36	29		13	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UWR -15		100	95	86	61	34	31		12	N/A	N/A	8	N/A	Failed	Passed	N/A	N/A
UWR -16		100	100	93	70	54	42		19	N/A	N/A	5.7	N/A	Failed	Passed	N/A	N/A
UWR -17	100	90	82	77	55	36		20	8	20.6	13.1	7.5	45	Passed	Passed	Passed	Failed
UWR -18	100	99	97	90	65	35		22	13	34.6	20.5	14.1	73	Failed	Failed	Failed	Failed
UWR -19		100	99	94	70	48		28	13	21.2	17	4.2	47	Passed	Passed	Passed	Failed
UWR -20	100	83	86	76	50	29		20	8	23	18.5	4.5	60	Failed	Passed	Passed	Failed

Table D2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Base specifications

Sample Identification	Grading (Percentage Passing)								Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
UWR -21	100	86	65	48	31	21	14	7	26.5	17.1	9.4	50	Failed	Passed	Failed	Failed
UWR -22			100	87	55	43	25	13	18.8	14.1	4.7	56	Passed	Passed	Passed	Failed
UWR -23		100	99	97	80	49	25	8	21	14.5	6.5	80	Failed	Passed	Passed	Passed
UWR -24		100	95	89	65	37	21	10	21.8	16.6	5.2	40	Failed	Passed	Passed	Failed
UWR -25	100	100	95	82	63	38	31	19	26.1	16.9	9.2	38	Failed	Passed	Failed	Failed
UWR -26	100	99	90	79	62	45	26	12	20	14.1	5.9	45	Failed	Passed	Passed	Failed
UWR -27	100	98	86	61	40	23	15	6	17.6	12.7	4.9	60	Failed	Passed	Passed	Failed
UWR -28	100	95	82	69	49	30	21	7	19.1	14.1	5	60	Failed	Passed	Passed	Failed
UWR -29			100	94	70	41	26	13	26.2	14.3	11.9	45	Failed	Failed	Failed	Failed
UWR -30		100	98	82	51	32	26	13	27.3	15.3	12	55	Failed	Failed	Failed	Failed
UWR -31		100	100	97	82	61	36	19	24.7	15.7	9	45	Failed	Passed	Passed	Failed
UWR -32		100	98	89	65	43	29	11	23.1	17.2	5.9	70	Failed	Passed	Passed	Failed
UWR -33		100	98	85	53	37	28	13	20.5	12.6	7.9	60	Failed	Passed	Passed	Failed
UWR -34	100	99	94	71	44	33	23	11	20.9	15.3	5.6	70	Failed	Passed	Passed	Failed
UWR -35		100	99	95	79	43	29	13	17.6	11.9	5.7	78	Failed	Passed	Passed	Failed
UWR -36	100	99	83	72	53	39	29	15	22.4	15.2	7.2	67	Failed	Passed	Passed	Failed
UWR -37	100	99	91	72	57	40	31	19	28.7	16.9	11.8	45	Failed	Failed	Failed	Failed
UWR -38		100	99	82	67	43	37	26	21.5	16.5	5	55	Failed	Passed	Passed	Failed
UWR -39		100	95	83	62	42	30	22	23.6	18.5	5.1	55	Failed	Passed	Passed	Failed
UWR -40			88			46	24	13	NP	NP	NP	100	Failed	Passed	Passed	Passed

Table D2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
UWR -41					52	33	17	24	19	5	30	Passed	Passed	Passed	Failed
UWR -42					35	25	16	23	19	4	95	Passed	Passed	Passed	Passed
UWR -43		98			34	17	13	26	25	1	42	Failed	Passed	Failed	Failed
UWR -44		97			39	25	18	24	19	4	23	Failed	Passed	Passed	Failed
UWR -45		100			43	27	17	24	20	4	50	Failed	Passed	Passed	Failed
UWR -46		83			21	15	14	32	22	10	73	Failed	Passed	Failed	Failed
UWR -47					40	23	18	32	16	16	18	Failed	Failed	Failed	Failed
UWR -48		100			39	23	11	32	16	16	67	Failed	Failed	Failed	Failed
UWR -49		78			42	32	16	21	15	6	48	Failed	Passed	Passed	Failed
UWR -50		96			46	28	19	34	19	15	67	Failed	Failed	Failed	Failed
UWR -51		82			39	26	15	26	17	9	42	Failed	Passed	Failed	Failed
UWR -52		89			21	15	13	29	19	10	70	Failed	Passed	Failed	Failed
UWR -53		94			39	20	8	23	19	4	50	Failed	Passed	Passed	Failed
UWR -54		95			42	32	29	18	16	2	28	Failed	Passed	Passed	Failed
UWR -55		100			68	49	30	27	19	8	37	Failed	Passed	Failed	Failed
UWR -56		99			56	35	18	20	19	1	53	Failed	Passed	Passed	Failed
UWR -57		83			21	16	6	NP	NP	NP	128	Failed	Passed	Passed	Passed

Table D3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	13.2 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL< 25	CBR> 80
UER-1	100	100	99	94	91	76	57		15	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-2	100	100	92	81	75	66	57		20	N/A	N/A	17	N/A	Failed	Failed	N/A	N/A
UER-3	100	100	98	95	94	85	72		19	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-4	93	93	90	88	84	75	56		22	N/A	N/A	12	N/A	Failed	Failed	N/A	N/A
UER-5	100	100	99	98	81	72	60		18	N/A	N/A	18	N/A	Failed	Failed	N/A	N/A
UER-6	100	100	96	95	94	82	58		21	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-7	100	100	97	89	81	70	61		16	N/A	N/A	12	N/A	Failed	Failed	N/A	N/A
UER-8	100	100	95	91	88	72	63		16	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-9	100	100	93	91	85	73	52		18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-10	100	100	94	90	88	80	75		19	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
UER-11			79				24	13	7	NP	NP	NP	129	Passed	Passed	Passed	Passed
UER-12			93				40	22	14	22	15	7	60	Failed	Passed	Passed	Failed
UER-13		100				68	36	23		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-14		100				70	52	34		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-15		100				57	32	19		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-16		100				63	36	21		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-17		100				44	27	15		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

Table D3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Base specifications

Sample Identification	Gradation: Gravel %	Sand %	Silt+Clay %	Atterberg limits: L.L. %	P.L %	P.I %	CBR at 98%	Base specification: Grading	PI≤ 10	LL< 25	CBR> 80
UER-18	75	9	16	21	14	7	21	N/A	Passed	Passed	Failed
UER-19	61	21	18	21	14	7	33	N/A	Passed	Passed	Failed

Table D4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Base specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR> 80
AR-1	100	100	89	58	45	38	33	24	23	22	22	44	21	23	N/A	Failed	Failed	Failed	N/A
AR-2	100	100	82	59	43	43	33	27	21	19	18	35	19	15	N/A	Failed	Failed	Failed	N/A
AR-3	100	100	75	57	52	47	41	32	28	21	19	36	17	19	N/A	Failed	Failed	Failed	N/A
AR-4	100	100	78	59	47	37	31	21	17	15	14	33	17	16	N/A	Passed	Failed	Failed	N/A
AR-5	100	100	99	94	81	72	57	32	24	21	18	31	16	15	N/A	Failed	Failed	Failed	N/A
AR-6	100	100	98	91	80	65	54	37	33	28	15	37	20	17	N/A	Failed	Failed	Failed	N/A
AR-7	100	100	92	87	81	69	57	39	33	31	26	40	22	19	N/A	Failed	Failed	Failed	N/A
AR-8	-	-	-	-	-	-	-	-	-	-	-	44	20	24	N/A	N/A	Failed	Failed	N/A
AR-9	100	92	77	66	55	38	29	21	19	18	16	52	29	24	N/A	Passed	Failed	Failed	N/A
AR-10	100	100	100	98	89	64	48	28	24	21	15	52	25	26	N/A	Failed	Failed	Failed	N/A
AR-11	100	100	99	94	89	75	62	41	35	31	25	49	26	23	N/A	Failed	Failed	Failed	N/A
AR-12	100	100	100	92	60	48	36	24	20	14	11	24	14	9	N/A	Failed	Passed	Passed	N/A
AR-13	100	100	91	85	75	54	42	23	18	15	10	43	26	17	N/A	Failed	Failed	Failed	N/A
AR-14	100	100	97	90	84	73	61	38	33	30	28	53	25	28	N/A	Failed	Failed	Failed	N/A
AR-15	93	85	70	55	42	34	30	23	21	18	14	38	20	18	N/A	Failed	Failed	Failed	N/A
AR-16	100	97	90	86	79	74	70	57	42	29	23	46	22	24	N/A	Failed	Failed	Failed	N/A
AR-17	100	95	83	76	68	62	52	38	31	28	24	42	21	21	N/A	Failed	Failed	Failed	N/A
AR-18			92					33		24	21	28	17	11	38	Failed	Failed	Failed	Failed
AR-19			90					24		18	12	22	17	5	38	Failed	Passed	Passed	Failed
AR-20			92					18		12	9	25	18	7	98	Failed	Passed	Passed	Passed

Table D4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region with compared to Base specifications

Sample Identification	Grading: Percentage Passing							Atterberg Test			CBR at 98%	Base Specifications			
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR> 80
AR-21		89			22	17	14	34	15	19	76	Failed	Failed	Failed	Failed
AR-22		92			45	21	18	36	22	12	35	Failed	Failed	Failed	Failed
AR-23		91			24	15	10	25	17	8	78	Failed	Passed	Passed	Failed
AR-24		94			50	28	16	24	16	8	56	Failed	Passed	Passed	Failed
AR-25		95			35	20	13	32	24	8	99	Failed	Failed	Failed	Passed
AR-26		98			36	20	10	27	15	12	60	Failed	Failed	Failed	Failed
AR-27		94			15	11	8	23	17	6	94	Failed	Passed	Passed	Passed
AR-28		91			12	7	5	23	16	7	138	Failed	Passed	Passed	Passed
AR-29		92			26	22	19	32	25	7	18	Failed	Passed	Failed	Failed
AR-30		93			37	29	23	49	20	29	40	Failed	Failed	Failed	Failed
AR-31		87			45	17	5	36	19	17	40	Failed	Failed	Failed	Failed
AR-32		89			36	25	19	39	22	16	50	Failed	Failed	Failed	Failed
AR-33		94			39	31	25	33	20	12	35	Failed	Failed	Failed	Failed
AR-34		70			26	19	14	42	19	23	35	Passed	Failed	Failed	Failed
AR-35		87			34	25	19	17	9	8	90	Failed	Passed	Passed	Passed
AR-36		95			42	25	16	28	16	12	100	Failed	Failed	Failed	Passed
AR-37		85			18	13	9	19	10	9	89	Failed	Passed	Passed	Passed
AR-38		84			22	16	11	18	9	9	64	Failed	Passed	Passed	Failed
AR-39		86			20	14	10	23	15	8	95	Failed	Passed	Passed	Passed
AR-40		72			30	23	20	43	23	20	35	Failed	Failed	Failed	Failed

Table D4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 75 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
AR-41		69			29	25	21	37	21	16	40	Failed	Failed	Failed	Failed
AR-42		90			34	19	14	27	16	11	60	Failed	Failed	Failed	Failed
AR-43		71			31	24	21	36	19	17	47	Failed	Failed	Failed	Failed
AR-44		88			43	16	11	29	16	13	60	Failed	Failed	Failed	Failed
AR-45		89			27	19	13	20	11	9	65	Failed	Passed	Passed	Failed
AR-46		90			29	21	14	27	10	17	45	Failed	Failed	Failed	Failed
AR-47		90			38	29	19	23	12	11	80	Failed	Failed	Passed	Passed
AR-48		90			37	29	15	30	16	14	80	Failed	Failed	Failed	Passed
AR-49		90			34	22	14	23	11	12	87	Failed	Failed	Passed	Passed
AR-50		84			19	14	9	17	9	8	82	Failed	Passed	Passed	Passed
AR-51		90			36	29	21	35	23	16	40	Failed	Failed	Failed	Failed
AR-52		84			20	14	10	24	14	10	95	Failed	Passed	Passed	Passed
AR-53		86			20	15	11	24	14	10	100	Failed	Passed	Passed	Passed
AR-54		85			31	24	10	31	19	12	60	Failed	Failed	Failed	Failed
AR-55		96			26	21	16	39	20	19	60	Failed	Failed	Failed	Failed
AR-56		94			22	14	9	23	11	12	100	Failed	Failed	Passed	Passed
AR-57		87			25	17	11	21	10	11	82	Failed	Failed	Passed	Passed
AR-58		98			37	26	18	28	16	12	87	Failed	Failed	Failed	Failed
AR-59		84			19	14	9	19	10	9	73	Failed	Passed	Passed	Failed
AR-60		86			18	13	10	22	12	10	93	Failed	Passed	Passed	Passed

Table D4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
AR-61				88			26	18	14	34	17	17	98	Failed	Failed	Failed	Passed
AR-62				91			26	17	9	23	11	12	52	Failed	Failed	Passed	Failed
AR-63				88			22	22	14	24	12	12	100	Failed	Failed	Passed	Passed
AR-64	100		100	100	95	75	56	40	27	38	18	20	75	Failed	Failed	Failed	Failed
AR-65	100		100	92	86	70	49	29	18	28	17	11	57	Failed	Failed	Failed	Failed
AR-66	100		100	91	81	61	46	29	17	30	18	12	50	Failed	Failed	Failed	Failed
AR-67				100			43	31	26	46	12	34	33	Failed	Failed	Failed	Failed

Sample Identification	Gradation: Gravel %	Sand %	Silt+Clay %	Atterberg Limits: L.L. %	P.L %	P.I %	CBR at 98%	Base specification: Grading	PI< 10	LL< 25	CBR> 80
AR-68	81	10	9	N/A	N/A	N/A	58	N/A	N/A	N/A	Failed
AR-69	88	6	6	N/A	N/A	N/A	103	N/A	N/A	N/A	Passed
AR-70	52	16	32	N/A	N/A	N/A	42	N/A	N/A	N/A	Failed
AR-71	65	19	6	N/A	N/A	N/A	66	N/A	N/A	N/A	Passed
AR-72	56	24	20	N/A	N/A	N/A	95	N/A	N/A	N/A	Passed
AR-73	82	10	8	N/A	N/A	N/A	23	N/A	N/A	N/A	Failed
AR-74	59	20	21	N/A	N/A	N/A	96	N/A	N/A	N/A	Passed
AR-75	68	15	17	N/A	N/A	N/A	58	N/A	N/A	N/A	Failed

Table D5: Grading, CBR and Atterberg's Limits of natural gravels in the Western compared to Base Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
WR-1	100	94.6	85	76.9	69	53	46.8	32.6	29.8	25.9	20.3	N/A	N/A	8	N/A	Failed	Passed	N/A	N/A
WR-2	100	100	79	63	47	38	29.7	25.9	23.1	20.4	16.3	N/A	N/A	11	N/A	Failed	Failed	N/A	N/A
WR-3	100	100	88	80.3	73	64	54.1	33.2	30.4	27.6	18.9	N/A	N/A	12	N/A	Failed	Failed	N/A	N/A
WR-4	93	90	79	73	62	55	48	41	38	25	13	N/A	N/A	4.5	N/A	Passed	Passed	N/A	N/A
WR-5	100	95	88	85	80	74	68	54	47	31	19	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
WR-6	97	95	81	73	67	59	51	39	33	24	17	N/A	N/A	12.4	N/A	Failed	Failed	N/A	N/A
WR-7	100	100	85	80.9	77	64	51.4	29.8	27.3	24.7	19.6	N/A	N/A	11	N/A	Failed	Failed	N/A	N/A
WR-8	100	100	86	77.3	69	62	55.8	46.9	39.5	32	20.2	N/A	N/A	14.4	N/A	Failed	Failed	N/A	N/A
WR-9	100	100	95	89.9	85	74	62.8	44	41.5	38.9	36.1	N/A	N/A	22	N/A	Failed	Failed	N/A	N/A
WR-10	100	100	95	88.8	82	62	49	33.6	29	27.4	21	N/A	N/A	8.4	N/A	Failed	Passed	N/A	N/A
WR-11	98.8	96.3	90	86.2	82	75	67.4	36.4	28.2	18.6	12.7	N/A	N/A	2.8	N/A	Failed	Passed	N/A	N/A
WR-12	100	72.8	61	52.7	44	30	25.1	20.4	15.8	12.8	7.9	N/A	N/A	13	N/A	Failed	Failed	N/A	N/A
WR-13	100	98.3	84	65.8	54	41	38	27.1	24.2	19.9	16	N/A	N/A	18.5	N/A	Failed	Failed	N/A	N/A
WR14	100	100	91	85	78	65	59.8	44.8	36.5	25.5	17.7	N/A	N/A	9.9	N/A	Failed	Passed	N/A	N/A
WR-15	97	91	85	77.4	67	53	47	31.6	28.4	21.7	16.7	N/A	N/A	8.5	N/A	Failed	Passed	N/A	N/A
WR-16	89.4	81.6	51	47	42	33	25.3	20	16.5	13.6	11	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
WR-17	100	97.5	96	90.4	83	68	55.5	37.3	31.2	28.7	22	N/A	N/A	13.5	N/A	Failed	Failed	N/A	N/A
WR-18	96.3	94.7	92	87.1	81	69	58.2	39.1	33	27.8	14.8	N/A	N/A	8.6	N/A	Failed	Passed	N/A	N/A
WR-19	96.2	93.3	88	79.9	72	53	44.4	32.9	30.1	28.5	18.1	N/A	N/A	7.5	N/A	Failed	Passed	N/A	N/A
WR-20	100	100	83		53		36	30		27	23	26	16	10	88	Failed	Passed	Failed	Passed

Table D5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
WR-21	100	100	84	53	37	31	27	22	33	18	15	68	Failed	Failed	Failed	Failed
WR-22	100	100	71	55	44	38	31	26	31	17	14	68	Failed	Failed	Failed	Failed
WR-23	100	100	89	66	45	38	34	28	30	21	9	68	Failed	Passed	Failed	Failed
WR-24	100	92	66	39	27	23	21	20	29	16	13	82	Failed	Failed	Failed	Passed
WR-25	100	100	88	74	36	24	21	18	35	20	15	80	Failed	Failed	Failed	Passed
WR-26	100	100	92	67	34	28	20	17	36	25	11	80	Failed	Failed	Failed	Passed
WR-27	100	100	85	63	42	35	31	27	34	22	12	82	Failed	Failed	Failed	Passed
WR-28	100	100	82	58	38	31	28	25	37	24	13	60	Failed	Failed	Failed	Failed
WR-29	100	100	87	68	53	45	40	33	28	14	14	55	Failed	Failed	Failed	Failed
WR-30	100	100	86	62	33	26	24	21	33	23	10	59	Failed	Passed	Failed	Failed
WR-31	100	100	89	73	43	34	32	30	41	29	12	52	Failed	Failed	Failed	Failed
WR-32	100	100	83	71	57	50	47	44	42	23	19	58	Failed	Failed	Failed	Failed
WR-33	100	100	72	43	29	24	21	18	29	16	13	79	Failed	Failed	Failed	Failed
WR-34	100	100	83	48	31	24	19	14	20	15	5	180	Failed	Passed	Passed	Passed
WR-35	100	100	83	62	44	37	32	28	31	18	13	72	Failed	Failed	Failed	Failed
WR-36	100	100	84	58	31	22	19	17	32	19	13	102	Failed	Failed	Failed	Passed
WR-37		100	100	87	45	30	25	21	35	20	15	45	Failed	Failed	Failed	Failed
WR-38		100	98	82	50	36	32	27	42	24	17	42	Failed	Failed	Failed	Failed
WR-39		100	94	75	52	42	38	30	39	25	14	60	Failed	Failed	Failed	Failed
WR-40		100	96	85	61	43	37	31	39	24	15	52	Failed	Failed	Failed	Failed

Table D5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
WR-41	100	99	90	57	45	37	30	38	25	13	22	Failed	Failed	Failed	Failed
WR-42	100	91	70	51	42	36	25	34	24	10	48	Failed	Passed	Failed	Failed
WR-43	97	96	86	48	37	32	24	34	23	11	54	Failed	Failed	Failed	Failed
WR-44	98	97	85	53	40	35	31	44	26	18	86	Failed	Failed	Failed	Passed
WR-45	100	93	75	49	40	37	35	58	35	24	64	Failed	Failed	Failed	Failed
WR-46	100	91	56	40	28	29	26	50	32	18	55	Failed	Failed	Failed	Failed
WR-47	100	94	72	45	38	34	26	40	25	15	59	Failed	Failed	Failed	Failed
WR-48	100	89	69	62	31	27	23	39	25	14	88	Failed	Failed	Failed	Passed
WR-49	100	92	67	45	34	27	25	43	28	16	95	Failed	Failed	Failed	Passed
WR-50					30	27	19	40	25	15	30	Failed	Failed	Failed	Failed
WR-51					34	27	16	28	19	9	48	Failed	Passed	Failed	Failed
WR-52					27	22	20	39	32	7	23	Failed	Passed	Failed	Failed
WR-53					34	26	14	34	21	14	16	Failed	Failed	Failed	Failed
WR-54					22	17	13	25	17	8	48	Passed	Passed	Passed	Failed
WR-55					20	14	11	38	22	15	36	Passed	Failed	Failed	Failed
WR-56					37	29	18	24	16	8	56	Failed	Passed	Passed	Failed
WR-57					26	22	18	21	14	7	31	Failed	Passed	Passed	Failed
WR-58					24	19	14	35	19	13	22	Passed	Failed	Failed	Failed
WR-59					45	38	32	45	23	22	14	Failed	Failed	Failed	Failed
WR-60					33	24	19	35	23	12	44	Failed	Failed	Failed	Failed

Table D5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 10	LL≤ 25	CBR≥ 80
WR-61					24	18	15	35	19	16	37	Passed	Failed	Failed	Failed
WR-62					32	16	12	30	20	10	40	Passed	Passed	Failed	Failed
WR-63					29	23	20	44	26	18	28	Failed	Failed	Failed	Failed
WR-64					38	32	28	44	30	14	16	Failed	Failed	Failed	Failed
WR-65					31	26	22	43	29	14	34	Failed	Failed	Failed	Failed
WR-66					26	18	11	23	18	5	53	Passed	Passed	Passed	Failed
WR-67					29	22	18	36	21	15	34	Failed	Failed	Failed	Failed
WR-68					44	38	28	39	23	16	17	Failed	Failed	Failed	Failed
WR-69					34	29	23	40	30	11	48	Failed	Failed	Failed	Failed
WR-70					33	26	16	23	13	10	59	Failed	Passed	Passed	Failed
WR-71					40	33	24	37	20	18	13	Failed	Failed	Failed	Failed
WR-72					22	16	12	32	19	13	31	Passed	Failed	Failed	Failed

Table D6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Base specifications

Sample Identification	Grading (Percentage Passing)										Atterberg Test			CBR at 98%	Base Specifications			
	37.5	20	13.2	10	6.7	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 10	LL≤ 25	CBR> 80
BAR-1	100	95	91.6	88	84	69.6	41.1	40.3	39.2	30	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
BAR-2	100	93	88.9	86	76	65.9	47.9	41.3	37.5	30	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-3	100	84	72.9	65	51	45	16.4	32.9	30.8	26.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-4	100	99	93.7	87	67	50.4	29.7	29.3	25.6	17	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-5	100	97	93.9	85	63	45.4	21.5	17.3	16.3	10.2	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
BAR-6	100	100	100	98	90	74.7	37.2	28.2	24.9	12.6	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-7	100	95	80.3	72	58	48.2	41.3	38.2	36.2	18.3	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-8	100	74	58.6	54	47	43.7	39.4	37.8	33.4	14.6	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-9	100	97	92.7	88	75	62	34.9	28.2	23.6	14.5	N/A	N/A	10.2	N/A	Failed	Failed	N/A	N/A
BAR-10	100	90	79.2	74	55	39	17	9.5	7.7	5.3	N/A	N/A	2.4	N/A	Failed	Passed	N/A	N/A
BAR-11	100	90	68	54	41	37.3	34.3	31.9	25.3	11	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-12	95.6	89	83.4	77	67	55.8	35.2	27.2	21	15.6	N/A	N/A	16.2	N/A	Failed	Failed	N/A	N/A
BAR-13	100	93	92.1	91	77	63.3	34.6	26.4	22.9	19.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-14	100	87	77	66	51	35.9	18.3	14.9	13.1	10.9	N/A	N/A	11	N/A	Failed	Failed	N/A	N/A
BAR-15	100	97	92	88	76	63.8	50.1	46.9	43	29.8	N/A	N/A	15	N/A	Failed	Failed	N/A	N/A
BAR-16	100	99	92	84	70	55.3	52	51.2	45.1	28.6	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
BAR-17							27		19	16	33	17	15	60	Failed	Failed	Failed	Failed
BAR-18							22		14	10	19	14	5	63	Failed	Passed	Passed	Failed
BAR-19							37		27	23	35	16	19		Failed	Failed	Failed	
BAR-20							28		21	18	45	25	20	36	Failed	Failed	Failed	Failed

Table D6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Base specifications

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Base specification			
	Gravel %	Sand %	Silt+Cla y %	L. L. %	P. L %	P. I. %		Grading	PI< 10	LL< 25	CBR> 80
BAR-21	75	11	14	18	14	4	44	N/A	Passed	Passed	Failed
BAR-22	88	12	0	23	18	5	83	N/A	Passed	Passed	Passed
BAR-23	70	19	11	15	12	3	46	N/A	Passed	Passed	Failed

Table D7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region with compared to Base Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
ER-1	100		91.7	50	38	26.9	19.7	15.9	10.7	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-2	100		86.7	50	37	26.5	19.5	15.75	12.3	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-3	100		95.1	85	77	58	43.5	22.3	11	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-4	98		91.4	76	63	52.5	46.2	28.2	21.4	N/A	N/A	16.3	N/A	Failed	Failed	N/A	N/A
ER-5	97		86.1	76	66	53.5	47.6	31.4	25.9	N/A	N/A	13.3	N/A	Failed	Failed	N/A	N/A
ER-6	100		93	78	64	53.4	46.6	28.9	27.9	N/A	N/A	19.7	N/A	Failed	Failed	N/A	N/A
ER-7	98		88.8	72	58	48.7	42.5	25.2	19.4	N/A	N/A	19.6	N/A	Failed	Failed	N/A	N/A
ER-8	100		100	100	76	56.1	40.5	31.3	22.1	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-9	100		100	100	88	70	42	34	30	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-10	100		100	100	90	72	53	19	12	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-11			95	86	60	50	41	26	18	25	18	N/A	91	Failed	Passed	Passed	Passed
ER-12			98	94	86	69	39	18	9	21	15	6	134	Failed	Passed	Passed	Passed
ER-13			92	83	76	60	43	26	16	25	14	11	75	Failed	Failed	Passed	Failed
ER-14			95	83	67	45	27	17	10	23	17	6	99	Failed	Passed	Passed	Passed
ER-15			94	80	64	49	28	15	7	26	15	11	105	Failed	Failed	Failed	Passed
ER-16			95	83	72	57	42	21	9	23	11	12	57	Failed	Failed	Passed	Failed
ER-17	100	99		96	81	54	38	30	15	45	23	22	38	Failed	Failed	Failed	Failed
ER-18	100	100		100	87	57	38	30	15	47	23	24	N/A	Failed	Failed	Failed	N/A
ER-19	100	100		98	86	55	37	28	12	43	22	21	N/A	Failed	Failed	Failed	N/A
ER-20	100	95	86	68	45	37	31	25	13	28	16	12	40	Passed	Failed	Failed	Failed

Table D7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			CBR at 98%	Base Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI< 10	LL≤ 25	CBR≥ 80
ER-21	99	97	93	80	65	54	45	38	33	15	19	13	6	21	Failed	Passed	Passed	Failed
ER-22	98	94	88	72	61	50	42	38	31	16	23	13	10	45	Failed	Passed	Passed	Failed
ER-23	100	99	95	80	61	49	38	35	34	28	40	21	19	21	Failed	Failed	Failed	Failed
ER-24	100	99	96	81	61	46	35	29	23	14	37	21	16	35	Passed	Failed	Failed	Failed

Table D8: Grading, CBR and Atterberg's Limits of natural gravels in the Central Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 95%	Base Specifications			
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
CR-1		100	92	85	78	62	49	26	19	16	13	43.5	26.8	16.7	N/A	Failed	Failed	Failed	N/A
CR-2		100	89	81	74	62	55	41	33	23	15	25.9	15.7	10.2	N/A	Failed	Failed	Failed	N/A
CR-3		100	88	83	77	61	49	31	25	22	18	42.8	29.8	13	N/A	Failed	Failed	Failed	N/A
CR-4		100	89	82	76	65	57	44	40	28	17	22.8	15.4	7.4	N/A	Failed	Passed	Passed	N/A
CR-5		100	77	64	54	43	36	28	24	21	17	33.5	20.2	13.3	N/A	Failed	Failed	Failed	N/A
CR-6		100	92	82	75	64	55	35	26	21	16	33.7	21.7	12	N/A	Failed	Failed	Failed	N/A
CR-7		100	87	82	76	66	60	41	30	20	13	24.7	15.9	8.8	N/A	Failed	Passed	Passed	N/A
CR-8		100	78	69	62	52	47	38	33	29	23	32.1	20	12.1	N/A	Failed	Failed	Failed	N/A
CR-9		100	85	76	68	57	49	35	28	21	14	31.5	18.7	12.8	N/A	Failed	Passed	Failed	N/A
CR-10		100	91	90	78	68	62	48	38	31	23	38.9	20	18.9	N/A	Failed	Failed	Failed	N/A
CR-11		100	94	90	87	78	71	49	38	28	20	30.7	18.4	12.3	N/A	Failed	Failed	Failed	N/A
CR-12		100	92	90	86	78	72	60	51	41	34	38.9	22	16.9	N/A	Failed	Failed	Failed	N/A
CR-13	100	100	90		61		31	24		17	13	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
CR-14	100	100	97		72		50	37		29	24	N/A	N/A	15	N/A	Failed	Failed	N/A	N/A
CR-15	100	95	74		48		33	25		18	14	N/A	N/A	14	N/A	Passed	Failed	N/A	N/A
CR-16	100	100	91		75		49	34		15	9	N/A	N/A	8	N/A	Failed	Passed	N/A	N/A
CR-17	100	100	87		78		53	38		16	7	N/A	N/A	4	N/A	Failed	Passed	N/A	N/A
CR-18	100	97	92		83		62	34		13	9	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
CR-19	100	100	96		87		67	44		21	15	N/A	N/A	11	N/A	Failed	Failed	N/A	N/A
CR-20	100	100	89		70		53	41		29.5	18	N/A	N/A	8.5	N/A	Failed	Passed	N/A	N/A

Table D8: Grading, CBR and Atterberg's Limits of natural gravels in the Central Region to Base Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
CR-21		100	98	81	64	50	35	18	17	N/A	N/A	14	N/A	Passed	Failed	N/A	N/A
CR-22		100	98	86	76	58	45	25	24	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
CR-23		100	100	100	93	79	40	17.5	11.5	N/A	N/A	11.8	N/A	Failed	Failed	N/A	N/A
CR-24		100	100	100	89	66	54	37.75	21.5	N/A	N/A	19.1	N/A	Failed	Failed	N/A	N/A
CR-25		100	100	100	81	58	39	22.9	17	N/A	N/A	12.9	N/A	Failed	Failed	N/A	N/A
CR-26		100	100	98	88	72	52	31.5	8.5	N/A	N/A	4.2	N/A	Failed	Passed	N/A	N/A
CR-27	100		95	91	84	69	43	21	11	23	12	11	106	Failed	Failed	Passed	Passed
CR-28	99		95	90	83	70	40	22	15	35	17	19	60	Failed	Failed	Failed	Failed
CR-29	100		96	91	81	69	45	22	15	29	14	15	90	Failed	Failed	Failed	Passed
CR-30	98		93	91	83	67	40	29	9	23	10	13	63	Failed	Failed	Passed	Failed
CR-31	99		96	94	86	65	35	20	10	25	11	14	87	Failed	Failed	Passed	Failed
CR-32	100		95	89	78	73	38	22	9	20	10	10	237	Failed	Passed	Passed	Passed
CR-33	100		99	97	90	76	42	21	12	27	12	15	99	Failed	Failed	Failed	Passed
CR-34	100		97	94	85	62	27	14	5	11	5	6	139	Failed	Passed	Passed	Passed
CR-35	100		98	93	83	62	38	19	9	17	9	8	101	Failed	Passed	Passed	Passed
CR-36	100		97	93	88	73	44	26	12	10	5	5	139	Failed	Passed	Passed	Passed
CR-37	99		95	86	76	57	32	20	10	34	13	21	72	Failed	Failed	Failed	Failed
CR-38	99		93	87	78	52	44	36	29	61	24	37	10	Failed	Failed	Failed	Failed
CR-39	100	100	97	91	85	70	30	12	7	28	14	14	42	Failed	Failed	Failed	Failed
CR-40	100		97	92	82	64	46	30	35	65	29	36	14	Failed	Failed	Failed	Failed

Table D8: Grading, CBR and Atterberg's Limits of natural gravels in the Central Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Base Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR≥ 80
CR-41	100		93	89	82		67	47		24	20	28	12	16	113	Failed	Failed	Failed	Passed
CR-42	100	99	97	93	88		68	48	40	38	30	43	23	20	34	Failed	Failed	Failed	Failed
CR-43	100	100	96	85	70		57	38	34	30	21	35	17	18	36	Failed	Failed	Failed	Failed
CR-44	100	100	98	94	87		66	34	31	30	26	53	28	25	47	Failed	Failed	Failed	Failed
CR-45	100	100	98	92	64		46	45	36	34	25	42	23	19	15	Failed	Failed	Failed	Failed
CR-46	100	96	91	78	47		36	32	30	26	18	30	16	14	20	Failed	Failed	Failed	Failed
CR-47	100	100	92	84	56		38	26	23	22	20	62	27	35	26	Failed	Failed	Failed	Failed
CR-48	100	100	98	92	80		56	34	28	27	22	57	23	34	38	Failed	Failed	Failed	Failed
CR-49	100	100	96	85	62		46	39	37	33	26	44	21	23	38	Failed	Failed	Failed	Failed
CR-50	100	84	80	70	53		45	33	29	28	23	43	27	16	27	Failed	Failed	Failed	Failed
CR-51	100	100	96	86	66		46	31	23	20	15	42	23	19	20	Passed	Failed	Failed	Failed
CR-52	100	83	80	67	55		42	33	29	27	20	41	21	20	23	Failed	Failed	Failed	Failed
CR-53	100	99	96	88	63		48	21	13	8	1	36	19	16	74	Failed	Failed	Failed	Failed
CR-54	100	100	94	84	69		51	37	27	27	11	34	13	11	51	Failed	Failed	Failed	Failed
CR-55		100	98	90	69	59	50	33	24	16	5	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
CR-56		100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A

Table D9: Grading, CBR and Atterberg's Limits of natural gravels in the Volta Region compared to Base specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	53	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 10	LL< 25	CBR≥ 80
VR-1	100	98	85		58	44		25	14			8.8	N/A	Failed	Passed	N/A	N/A
VR-2	100	96	61		29	19		11	9			8.8	N/A	Failed	Passed	N/A	N/A
VR-3	100	92	74		52	41		26	14			7	N/A	Passed	Passed	N/A	N/A
VR-4	100	100	53		64	56		28	22			14.7	N/A	Failed	Failed	N/A	N/A
VR-5	100	100	65		44	25		17	10			6.1	N/A	Passed	Passed	N/A	N/A
VR-6	100	100	72		52	38		21	13			4.3	N/A	Passed	Passed	N/A	N/A
VR-7	100	100	53		74	79		51	13			4.3	N/A	Failed	Passed	N/A	N/A
VR-8	100	100	70		52.5	36		23	18			9	N/A	Passed	Passed	N/A	N/A
VR-9	100	100	87		61	43		23	22			7.7	N/A	Failed	Passed	N/A	N/A
VR-10	100	96	84		60	51		29	16			6.2	N/A	Failed	Passed	N/A	N/A
VR-11	100	91	78		57	53		26	14			7.4	N/A	Failed	Passed	N/A	N/A
VR-12		99	98	63	29	24	22		14	39	22	17	50	Failed	Failed	Failed	Failed
VR-13			100	69	33	26	23		14	45	24	21	45	Failed	Failed	Failed	Failed
VR-14		100	99	71	38	20	17		8	40	25	15	55	Failed	Failed	Failed	Failed
VR-15			100	81	44	25	17		14	33	18	15	64	Failed	Failed	Failed	Failed
VR-16		100	98	86	47	24	20		12	28	17	11	60	Failed	Failed	Failed	Failed
VR-17		100	97	87	56	38	32		18	23	15	8	50	Failed	Passed	Passed	Failed
VR-18		100	98	86	57	3	33		14	21	14	7	70	Failed	Passed	Passed	Failed
VR-19		100	97	86	34	17	12		4	25	19	6	50	Failed	Passed	Passed	Failed
VR-20		100		73	36	16	12		6	28	18	10	57	Failed	Passed	Failed	Failed

Table D9: Grading, CBR and Atterberg's Limits of natural gravels in the Volta Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	53	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI< 10	LL< 25	CBR> 80
VR-21	100		87	72	46	32	26		12	33	16	17	43	Failed	Failed	Failed	Failed
VR-22		100	99	77	48	32	27		18	46	26	20	45	Failed	Failed	Failed	Failed
VR-23			100	69	33	23	20		13	38	22	16	50	Failed	Failed	Failed	Failed
VR-24		99	98	63	29	21	17		12	39	21	18	40	Failed	Failed	Failed	Failed
VR-25			93			41		35	25	23	13	10	76	Failed	Passed	Passed	Failed
VR-26			100			43		27	7	21	20	1	168	Failed	Passed	Passed	Passed
VR-27			100			51		32	20	20	14	6	98	Failed	Passed	Passed	Passed
VR-28			100			43		34	23	23	17	6	66	Failed	Passed	Passed	Failed
VR-29			100			28		23	15	19	15	4	94	Failed	Passed	Passed	Passed
VR-30			99			33		26	21	20	14	6	96	Failed	Passed	Passed	Passed
VR-31			99			40		28	22	28	20	8	148	Failed	Passed	Failed	Passed
VR-32			99			36		25	20	27	20	7	98	Failed	Passed	Failed	Passed
VR-33			99			43		28	19	17	14	3	88	Failed	Passed	Passed	Passed
VR-34			95			37		33	24	19	13	6	60	Failed	Passed	Passed	Failed
VR-35			98			31		25	21	21	14	7	82	Failed	Passed	Passed	Passed
VR-36			99			27		22	16	20	4	16	81	Failed	Failed	Passed	Passed
VR-37			100			29		25	19	19	16	3	130	Failed	Passed	Passed	Passed
VR-38			100			49		31	21	19	16	3	53	Failed	Passed	Passed	Failed
VR-39			99			42		37	25	20	15	5	100	Failed	Passed	Passed	Passed

Table D10: Grading, CBR and Atterberg's Limits of natural gravels in the Greater Accra Region compared to Base specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 10	LL≤ 25	CBR> 80
GAR-1	100		98	79		55	41	33	27	18	22	12	10	80	Failed	Passed	Passed	Passed
GAR-2	100		100	91		62	39	31	25	14	20	14	6	N/A	Failed	Passed	Passed	N/A
GAR-3	100		100	81		57	37	32	28	16	19	12	7	N/A	Failed	Passed	Passed	N/A
GAR-4	100		93	70		54	46	43	38	22	18	11	7	50	Failed	Passed	Passed	Failed
GAR-5	100		99	97		81	52	41	33	20	29	16	13	22	Failed	Failed	Failed	Failed
GAR-6	100		100	96		68	41	33	26	16	23	12	11	N/A	Failed	Failed	Passed	N/A
GAR-7	100		100	91		72	39	28	21	14	24	13	11	N/A	Failed	Failed	Passed	N/A
GAR-8	100		100	95		77	48	37	31	19	24	11	13	N/A	Failed	Failed	Passed	N/A
GAR-9	100		98	83		58	43	35	13	17	22	9	13	50	Failed	Failed	Passed	Failed
GAR-10	100		100	89		70	37	27	19	11	20	10	10	N/A	Failed	Passed	Passed	N/A
GAR-11	99		91	77		58	36	29	22	14	28	15	13	50	Failed	Failed	Passed	Failed
GAR-12	100		98	92		73	48	33	26	17	22	12	10	N/A	Failed	Passed	Passed	N/A
GAR-13	100		95	87		68	42	30	24	15	24	13	11	N/A	Failed	Failed	Passed	N/A
GAR-14	100		96	80		59	38	32	24	15	19	11	8	N/A	Failed	Passed	Passed	N/A
GAR-15	100		97	87		67	38	28	21	12	24	14	10	70	Failed	Passed	Passed	Failed
GAR-16		96	85	67	53	46	34	24	15	8	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-17	100	98	92	68	51	44	34	30	25	15	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
GAR-18			100	96	83	74	52	42	33	19	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
GAR-19	100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-20	100	97	87	69	54	45	35	31	23	12	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
GAR-21		97	92	83		68	43		17	9	19	15	4	N/A	Failed	Passed	Passed	N/A

APPENDIX E:
COMPARING GRADING AND PLASTICITY INDEX OF NATURAL GRAVELS WITH OTTA SEAL REQUIREMENTS

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Table E1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			Otta Seal Specifications	
	75 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI< 10
NR-1	100	100	100	90	83	69	59	34	23	17	11	21.7	13.3	8.4	Failed	Passed
NR-2	100	100	100	93	87	68	49	23	15	13	11	24.3	15.7	8.6	Failed	Passed
NR-3	100	100	100	92	86	66	46	20	14	12	10	21.8	13.6	8.2	Passed	Passed
NR-4	100	100	100	91	82	63	51	30	23	20	17	22.6	15.1	7.5	Failed	Passed
NR-5	100	100	100	89	76	55	45	32	28	27	25	27.2	15.4	11.8	Failed	Failed
NR-6	100	100	100	98	91	77	65	44	34	29	23	26.3	15.4	10.9	Failed	Failed
NR-7	100	100	100	100	96	80	59	26	20	18	13	19.6	13.2	6.4	Failed	Passed
NR-8	100	100	100	97	90	77	64	33	21	17	14	33.5	20.7	12.8	Failed	Failed
NR-9	100	100	100		78		41.1	22.3	14.6	12.4	10.4	N/A	N/A	12	Failed	Failed
NR-10	100	100	100		95		58.5	33.8	23.9	20.2	16.8	N/A	N/A	11.1	Failed	Failed
NR-11	100	100	100		92		57.7	30.2	19.5	16.7	13	N/A	N/A	18.3	Failed	Failed
NR-12	100	100	100		90		63.7	46.8	42	38.8	25.6	N/A	N/A	17.3	Failed	Failed
NR-13	100	100	100		96		70.6	34.2	25.6	23.2	15.5	N/A	N/A	23.7	Failed	Failed
NR-14	100	100	100		87		53.6	27.2	17.7	13.9	9	N/A	N/A	13.3	Failed	Failed
NR-15	100	100	100		83		53.2	33	27.5	25.5	22.6	N/A	N/A	14.3	Failed	Failed
NR-16	100	100	100		99.5		88.4	40	24.2	21.5	14.4	N/A	N/A	12.3	Failed	Failed
NR-17	100	100	100		94		56.9	34.4	26.8	24	13.9	N/A	N/A	12.2	Failed	Failed
NR-18	100	100	100		97		70.9	33.6	24.8	23.4	15.4	N/A	N/A	12.7	Failed	Failed
NR-19	100	100	100		64		29.7	17.7	14	13	10.9	N/A	N/A	14.5	Failed	Failed
NR-20	100	100	100		99		93	63.2	47.2	38.1	33	N/A	N/A	16.1	Failed	Failed

Table E1: Grading, CBR and Atterberg's limits of natural gravels in the Northern compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			Otta Seal Specifications	
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI< 10
NR-21	100		100	100	85	47	24	18	16	12	N/A	N/A	16.4	Failed	Failed
NR-22	100		100	100	99	73	38	29	26	20	N/A	N/A	14	Failed	Failed
NR-23	100		100	100	97	73	39	30	28	19	N/A	N/A	12.2	Failed	Failed
NR-24	100		100	100	90	56	31	30	30	21	N/A	N/A	7.7	Failed	Passed
NR-25	100		100	100	97	57	33	27	26	19	N/A	N/A	3.9	Failed	Passed
NR-26	100		100	100	66	43	30	26	24	19	N/A	N/A	10.3	Failed	Failed
NR-27	100		100	100	94	56	31	25	24	17	N/A	N/A	14.3	Failed	Failed
NR-28		100	92	81	64	46	34		30	19	17.2	12.3	4.9	Failed	Passed
NR-29		100	91	78	53	36	31		29	14	17.8	12.3	5.5	Failed	Passed
NR-30			100	82	60	45	37		32	14	14.8	10.1	4.7	Failed	Passed
NR-31		100	98	84	63	42	30		25	13	17.8	10.6	7.2	Failed	Passed
NR-32		100	97	91	84	76	45		38	20	17.4	12.8	4.6	Failed	Passed
NR-33		100	95	92	79	50	32		20	6	17.4	12.7	4.7	Failed	Passed
NR-34		100	95	91	80	48	25		18	7	18.2	12.5	5.7	Failed	Passed
NR-35		100	96	90	78	60	40		32	23	17	13.5	3.5	Failed	Passed
NR-36			100	95	81	50	29		25	12	NP	NP	NP	Failed	Passed
NR-37		100	96	79	58	46	27		19	7	26.6	18	8.6	Failed	Passed
NR-38			100	91	84	64	45		36	14	21.2	14.7	6.5	Failed	Passed
NR-39		100	89	78	54	38	25		20	15	24.6	18.8	5.8	Failed	Passed
NR-40		100	96	89	68	40	25		11	6	22.2	17.2	5	Failed	Passed

Table E1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			Otta Seal Specifications	
	53	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI		
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	Grading	PI≤ 10
NR-41	100	97	92	86	57	33		25	19	21.8	14.9	6.9	Failed	Passed
NR-42	100	95	83	72	54	29		21	17	23.8	18.2	5.6	Failed	Passed
NR-43	100	95	89	76	60	43		29	13	19.8	13.8	6	Failed	Passed
NR-44		100	93	90	75	48		34	11	19.4	13.9	5.5	Failed	Passed
NR-45	100	97	92	80	59	37		22	9	17.8	13.4	4.4	Failed	Passed
NR-46		100	85	65	42	31	23	17	7	19	14	5	Failed	Passed
NR-47		100	90	70	41	24	20	18	14	18	13	5	Failed	Passed
NR-48		100	95	75	66	43	41	39	32	57	25	31	Failed	Failed
NR-49		100	91	70	40	20	14	15	10	19	13	6	Failed	Passed
NR-50		100	89	74	49	29	23	21	11	NP	NP	NP	Failed	Passed
NR-51		100	94	70	31	16	13	9	3	NP	NP	NP	Failed	Passed
NR-52		100	98	79	49	24	23	14	9	NP	NP	NP	Failed	Passed
NR-53		100	99	84	41	22	18	12	5	NP	NP	NP	Failed	Passed
NR-54		100	100	90	56	36	29	20	11	NP	NP	NP	Failed	Passed
NR-55		100	100	89	57	35	27	19	7	NP	NP	NP	Failed	Passed
NR-56		100	100	88	45	24	20	14	7	NP	NP	NP	Failed	Passed
NR-57		100	94	69	37	33	28	16	5	NP	NP	NP	Failed	Passed
NR-58		100	90	76	52	36	28	15	8	NP	NP	NP	Failed	Passed
NR-59		100	83	59	43	27	21	19	13	NP	NP	NP	Failed	Passed
NR-60		100	85	67	42	29	23	17	7	NP	NP	NP	Failed	Passed

Table E1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			Otta Seal Specifications	
	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI		
	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	Grading	PI≤ 10
NR-61	100	83	62	48	40	29	21	11	NP	NP	NP	Failed	Passed
NR-62	100	88	68	41	27	22	18	11	NP	NP	NP	Failed	Passed
NR-63	100	89	55	33	25	22	18	11	NP	NP	NP	Failed	Passed

Sample Identification	Gradation			Atterberg limits			Otta Seal Specifications	
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. L %	P. I %	Grading	PI≤ 10
NR-64	57	15	28	20	14	6	Failed	Passed
NR-65	81	7	12	20	15	5	Failed	Passed
NR-66	80	5	15	21	14	7	Failed	Passed
NR-67	76	5	19	29	19	10	Failed	Passed
NR-68	77	9	14	16	13	3	Failed	Passed

Table E2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			Otta Seal Specifications	
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
UWR-1		100	94	86	61	38	33		16	N/A	N/A	8	Failed	Passed
UWR-2		100	94	63	35	22	17		15	N/A	N/A	9	Failed	Passed
UWR-3		100	100	87	47	34	29		18	N/A	N/A	14	Failed	Failed
UWR-4		100	89	69	41	27	22		10	N/A	N/A	9	Failed	Passed
UWR-5		100	87	61	37	30	23		11	N/A	N/A	8	Failed	Passed
UWR-6		100	98	88	60	39	32		12	N/A	N/A	9.1	Failed	Passed
UWR-7		92	94	80	55	41	33		19	N/A	N/A	12	Failed	Failed
UWR-8		100	97	90	69	41	36		11	N/A	N/A	7	Failed	Passed
UWR-9		100	95	82	58	41	33		13	N/A	N/A	6	Failed	Passed
UWR-10		100	96	87	63	44	30		19	N/A	N/A	10	Failed	Passed
UWR-11		96	95	76	47	33	26		10	N/A	N/A	8	Failed	Passed
UWR-12		100	100	81	52	36	34		8	N/A	N/A	6	Failed	Passed
UWR-13		81	76	57	40	31	29		9	N/A	N/A	4	Failed	Passed
UWR-14		100	96	87	56	36	29		13	N/A	N/A	9	Failed	Passed
UWR-15		100	95	86	61	34	31		12	N/A	N/A	8	Failed	Passed
UWR-16		100	100	93	70	54	42		19	N/A	N/A	5.7	Failed	Passed
UWR-17	100	90	82	77	55	36		20	8	20.6	13.1	7.5	Failed	Passed
UWR-18	100	99	97	90	65	35		22	13	34.6	20.5	14.1	Failed	Failed
UWR-19		100	99	94	70	48		28	13	21.2	17	4.2	Failed	Passed
UWR-20	100	83	86	76	50	29		20	8	23	18.5	4.5	Failed	Passed

Table E 2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region with compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			Otta Seal Specifications	
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
UWR-21	100	86	65	48	31	21	14	7	26.5	17.1	9.4	Failed	Passed
UWR-22			100	87	55	43	25	13	18.8	14.1	4.7	Failed	Passed
UWR-23		100	99	97	80	49	25	8	21	14.5	6.5	Failed	Passed
UWR-24		100	95	89	62	37	21	10	21.8	16.6	5.2	Failed	Passed
UWR-25	100	100	95	82	63	38	31	19	26.1	16.9	9.2	Failed	Passed
UWR-26	100	99	90	79	62	45	26	12	20	14.1	5.9	Failed	Passed
UWR-27	100	98	86	61	40	23	15	6	17.6	12.7	4.9	Failed	Passed
UWR-28	100	95	82	69	49	30	21	7	19.1	14.1	5	Failed	Passed
UWR-29			100	94	70	41	26	13	26.2	14.3	11.9	Failed	Failed
UWR-30		100	98	82	51	32	26	13	27.3	15.3	12	Failed	Failed
UWR-31		100	100	97	82	61	36	19	24.7	15.7	9	Failed	Passed
UWR-32		100	98	89	65	43	29	11	23.1	17.2	5.9	Failed	Passed
UWR-33		100	98	85	53	37	28	13	20.5	12.6	7.9	Failed	Passed
UWR-34	100	99	94	71	44	33	23	11	20.9	15.3	5.6	Failed	Passed
UWR-35		100	99	95	79	43	29	13	17.6	11.9	5.7	Failed	Passed
UWR-36	100	99	83	72	55	39	29	15	22.4	15.2	7.2	Failed	Passed
UWR-37	100	99	91	72	57	40	31	19	28.7	16.9	11.8	Failed	Failed
UWR-38		100	99	82	67	43	37	26	21.5	16.5	5	Failed	Passed
UWR-39		100	95	83	62	42	30	22	23.6	18.5	5.1	Failed	Passed
UWR-40			88			46	24	13	NP	NP	NP	Failed	Passed

Table E2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region with compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI≤ 10
UWR-41					52	33	17	24	19	5	Failed	Passed
UWR-42					35	25	16	23	19	4	Failed	Passed
UWR-43		98			34	17	13	26	25	1	Failed	Passed
UWR-44		97			39	25	18	24	19	4	Failed	Passed
UWR-45		100			43	27	17	24	20	4	Failed	Passed
UWR-46		83			21	15	14	32	22	10	Failed	Passed
UWR-47					40	23	18	32	16	16	Failed	Failed
UWR-48		100			39	23	11	32	16	16	Failed	Failed
UWR-49		78			42	32	16	21	15	6	Failed	Passed
UWR-50		96			46	28	19	34	19	15	Failed	Failed
UWR-51		82			39	26	15	26	17	9	Failed	Passed
UWR-52		89			21	15	13	29	19	10	Failed	Passed
UWR-53		94			39	20	8	23	19	4	Failed	Passed
UWR-54		95			42	32	25	18	16	2	Failed	Passed
UWR-55		100			68	49	30	27	19	8	Failed	Passed
UWR-56		99			56	35	18	20	19	1	Failed	Passed
UWR-57		83			21	16	6	NP	NP	NP	Failed	Passed

Table E 3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	13.2 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI≤ 10
UER-1	100	100	99	94	91	76	57		15	N/A	N/A	10	Failed	Passed
UER-2	100	100	92	81	75	66	57		20	N/A	N/A	17	Failed	Failed
UER-3	100	100	94	95	94	85	72		19	N/A	N/A	9	Failed	Passed
UER-4	93	93	93	88	84	75	66		22	N/A	N/A	12	Failed	Failed
UER-5	100	100	93	90	81	72	60		18	N/A	N/A	18	Failed	Failed
UER-6	100	100	96	95	94	82	58		21	N/A	N/A	9	Failed	Passed
UER-7	100	100	97	89	81	70	61		16	N/A	N/A	12	Failed	Failed
UER-8	100	100	95	91	88	72	63		16	N/A	N/A	10	Failed	Passed
UER-9	100	100	92	91	85	73	52		18	N/A	N/A	9	Failed	Passed
UER-10	100	100	94	90	88	80	75		19	N/A	N/A	16	Failed	Failed
UER-11			79				24	13	7	NP	NP	NP	Failed	Passed
UER-12			91				40	22	14	22	15	7	Failed	Passed
UER-13		100				58	36	23		N/A	N/A	N/A	Failed	N/A
UER-14		100				70	52	34		N/A	N/A	N/A	Failed	N/A
UER-15		100				57	32	19		N/A	N/A	N/A	Failed	N/A
UER-16		100				63	36	21		N/A	N/A	N/A	Failed	N/A
UER-17		100				44	27	15		N/A	N/A	N/A	Failed	N/A

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Table E 3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Otta Seal specifications

Sample Identification	Gradation			Atterberg limits			Otta Seal Specifications	
	Gravel %	Sand %	Silt–Clay %	L. L. %	P. L %	P. I. %	Grading	PI< 10
UER-18	75	9	16	21	14	7	Failed	Passed
UER-19	61	21	18	21	14	7	Failed	Passed

Table E4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Otta Seal specifications

Sample Identification	Grading											Atterberg Test			Otta Seal Specifications	
	Percentage Passing															
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI< 10
AR-1	100	100	89	58	45	38	33	24	23	22	22	44	21	23	Failed	Failed
AR-2	100	100	82	59	49	43	33	27	21	19	18	35	19	15	Failed	Failed
AR-3	100	100	75	57	52	47	41	32	28	21	19	36	17	19	Failed	Failed
AR-4	100	100	78	59	47	37	31	21	17	15	14	33	17	16	Failed	Failed
AR-5	100	100	99	94	81	72	57	32	24	21	18	31	16	15	Failed	Failed
AR-6	100	100	98	91	80	65	54	37	33	28	15	37	20	17	Failed	Failed
AR-7	100	100	92	87	81	69	57	39	33	31	26	40	22	19	Failed	Failed
AR-8	-	-	-	-	-	-	-	-	-	-	-	44	20	24	N/A	Failed
AR-9	100	92	77	66	55	38	29	21	19	18	16	52	29	24	Failed	Failed
AR-10	100	100	100	98	89	64	48	28	24	21	15	52	25	26	Failed	Failed
AR-11	100	100	99	94	89	75	62	41	35	31	25	49	26	23	Failed	Failed
AR-12	100	100	100	72	60	48	36	24	20	14	11	24	14	9	Failed	Passed
AR-13	100	100	91	85	75	54	42	23	18	15	10	43	26	17	Failed	Failed
AR-14	100	100	97	90	84	73	61	38	33	30	28	53	25	28	Failed	Failed
AR-15	93	85	70	55	42	34	30	23	21	18	14	38	20	18	Failed	Failed
AR-16	100	97	90	86	79	74	70	57	42	29	23	46	22	24	Failed	Failed
AR-17	100	95	83	76	68	60	52	38	31	28	24	42	21	21	Failed	Failed
AR-18			92					35		24	21	28	17	11	Failed	Failed
AR-19			90					24		18	12	22	17	5	Failed	Passed
AR-20			92					18		12	9	25	18	7	Failed	Passed

Table E4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI< 10
AR-21		89			22	17	14	34	15	19	Failed	Failed
AR-22		92			45	21	18	36	22	12	Failed	Failed
AR-23		91			24	15	10	25	17	8	Failed	Passed
AR-24		94			30	28	16	24	16	8	Failed	Passed
AR-25		96			35	20	13	32	24	8	Failed	Failed
AR-26		98			36	20	10	27	15	12	Failed	Failed
AR-27		94			15	11	8	23	17	6	Failed	Passed
AR-28		91			12	7	5	23	16	7	Failed	Passed
AR-29		92			26	22	19	32	25	7	Failed	Passed
AR-30		93			37	27	23	49	20	29	Failed	Failed
AR-31		87			45	17	9	36	19	17	Failed	Failed
AR-32		89			36	25	19	39	22	16	Failed	Failed
AR-33		94			39	31	25	33	20	12	Failed	Failed
AR-34		70			26	19	14	42	19	23	Failed	Failed
AR-35		87			34	25	19	17	9	8	Failed	Passed
AR-36		95			42	25	16	28	16	12	Failed	Failed
AR-37		85			18	13	9	19	10	9	Failed	Passed
AR-38		84			22	16	11	18	9	9	Failed	Passed
AR-39		86			20	14	10	23	15	8	Failed	Passed
AR-40		72			30	23	20	43	23	20	Failed	Failed

Table E4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing 75 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI< 10
AR-41		69			30	25	21	37	21	16	Failed	Failed
AR-42		90			34	19	14	27	16	11	Failed	Failed
AR-43		71			31	24	21	36	19	17	Failed	Failed
AR-44		88			43	16	11	29	16	13	Failed	Failed
AR-45		89			27	19	13	20	11	9	Failed	Passed
AR-46		90			29	21	14	27	10	17	Failed	Failed
AR-47		90			38	29	19	23	12	11	Failed	Failed
AR-48		90			37	27	19	30	15	14	Failed	Failed
AR-49		90			34	22	14	23	11	12	Failed	Failed
AR-50		84			19	14	9	17	9	8	Failed	Passed
AR-51		93			36	29	21	39	23	16	Failed	Failed
AR-52		84			20	14	10	24	14	10	Failed	Passed
AR-53		86			20	15	11	24	14	10	Failed	Passed
AR-54		86			31	24	10	31	19	12	Failed	Failed
AR-55		96			26	21	16	39	20	19	Failed	Failed
AR-56		94			22	14	9	23	11	12	Failed	Failed
AR-57		87			25	17	11	21	10	11	Failed	Failed
AR-58		98			37	26	18	28	16	12	Failed	Failed
AR-59		84			19	14	9	19	10	9	Failed	Passed
AR-60		86			18	13	10	22	12	10	Failed	Passed

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Table E4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing 75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI< 10
AR-51				88			26	18	14	34	17	17	Failed	Failed
AR-52				91			26	17	9	23	11	12	Failed	Failed
AR-53				88			22	22	14	24	12	12	Failed	Failed
AR-54	100		100	100	95	75	55	40	27	38	18	20	Failed	Failed
AR-55	100		100	92	86	70	43	29	18	28	17	11	Failed	Failed
AR-56	100		100	91	81	61	46	29	17	30	18	12	Failed	Failed
AR-57				100			43	31	26	46	12	34	Failed	Failed

Sample Identification	Gradation: Gravel %	Sand %	Silt+ Clay %	Atterberg limits: L. L. %	P. L %	P. L %	Otta Seal Specifications: Grading	PI< 10
AR-68	81	10	9	N/A	N/A	N/A	N/A	N/A
AR-69	88	6	6	N/A	N/A	N/A	N/A	N/A
AR-70	52	16	32	N/A	N/A	N/A	N/A	N/A
AR-71	65	19	6	N/A	N/A	N/A	N/A	N/A
AR-72	56	24	20	N/A	N/A	N/A	N/A	N/A
AR-73	82	10	8	N/A	N/A	N/A	N/A	N/A
AR-74	59	20	21	N/A	N/A	N/A	N/A	N/A
AR-75	68	15	17	N/A	N/A	N/A	N/A	N/A

Table E5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI< 10
WR-1	100	94.6	85	76.9	69	53	45.8	32.6	29.8	25.9	20.3	N/A	N/A	8	Failed	Passed
WR-2	100	100	79	63	47	38	29.7	25.9	23.1	20.4	16.3	N/A	N/A	11	Failed	Failed
WR-3	100	100	88	80.3	73	64	54.1	33.2	30.4	27.6	18.9	N/A	N/A	12	Failed	Failed
WR-4	93	90	79	73	62	55	48	41	38	25	13	N/A	N/A	4.5	Failed	Passed
WR-5	100	95	88	85	80	74	68	54	47	31	19	N/A	N/A	12.2	Failed	Failed
WR-6	97	95	81	73	67	59	51	39	33	24	17	N/A	N/A	12.4	Failed	Failed
WR-7	100	100	85	80.9	72	64	51.4	29.8	27.3	24.7	19.6	N/A	N/A	11	Failed	Failed
WR-8	100	100	86	77.3	69	62	55.8	46.9	39.5	32	20.2	N/A	N/A	14.4	Failed	Failed
WR-9	100	100	95	89.9	85	74	62.8	44	41.5	35.9	36.1	N/A	N/A	22	Failed	Failed
WR-10	100	100	95	88.8	82	62	49	33.6	29	27.4	21	N/A	N/A	8.4	Failed	Passed
WR-11	98.8	96.3	90	86.2	82	75	67.4	36.4	28.2	18.6	12.7	N/A	N/A	2.8	Failed	Passed
WR-12	100	72.8	61	52.7	44	30	25.1	20.4	15.8	12.8	7.9	N/A	N/A	13	Failed	Failed
WR-13	100	98.3	84	65.8	54	41	38	27.1	24.2	19.9	16	N/A	N/A	18.5	Failed	Failed
WR14	100	100	91	85	78	65	59.8	44.8	36.5	25.5	17.7	N/A	N/A	9.9	Failed	Passed
WR-15	97	91	85	77.4	67	53	47	31.6	28.4	21.7	16.7	N/A	N/A	8.5	Failed	Passed
WR-16	69.4	61.6	51	47	42	33	25.5	20	16.5	13.6	11	N/A	N/A	16	Failed	Failed
WR-17	100	97.5	96	90.4	83	68	55.5	37.3	31.2	28.7	22	N/A	N/A	13.5	Failed	Failed
WR-18	96.3	94.7	92	87.1	81	69	58.2	39.1	33	27.8	14.8	N/A	N/A	8.6	Failed	Passed
WR-19	96.2	93.3	88	79.5	72	53	44.4	32.9	30.1	28.5	18.1	N/A	N/A	7.5	Failed	Passed
WR-20	100	100	83		53		36	30		27	23	26	16	10	Failed	Passed

Table E5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			Otta Seal Specifications	
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
WR-21	100	100	100	84	53	37	31	27	22	33	18	15	Failed	Failed
WR-22	100	100	100	71	55	44	38	31	26	31	17	14	Failed	Failed
WR-23	100	100	100	89	66	45	38	34	28	30	21	9	Failed	Passed
WR-24	100	100	92	66	39	27	23	21	20	29	16	13	Failed	Failed
WR-25	100	100	100	88	74	36	24	21	18	35	20	15	Failed	Failed
WR-26	100	100	100	92	67	34	28	20	17	36	25	11	Failed	Failed
WR-27	100	100	100	85	63	42	35	31	27	34	22	12	Failed	Failed
WR-28	100	100	100	82	58	38	31	28	25	37	24	13	Failed	Failed
WR-29	100	100	100	87	68	53	45	40	33	28	14	14	Failed	Failed
WR-30	100	100	100	86	62	33	26	24	21	33	23	10	Failed	Passed
WR-31	100	100	100	89	73	43	34	32	30	41	29	12	Failed	Failed
WR-32	100	100	100	83	71	57	50	47	44	42	23	19	Failed	Failed
WR-33	100	100	100	72	43	29	24	21	18	29	16	13	Failed	Failed
WR-34	100	100	100	83	48	31	24	19	14	20	15	5	Failed	Passed
WR-35	100	100	100	80	62	44	37	32	28	31	18	13	Failed	Failed
WR-36	100	100	100	84	58	31	22	19	17	32	19	13	Failed	Failed
WR-37			100	100	87	45	30	25	21	35	20	15	Failed	Failed
WR-38			100	98	82	58	36	32	27	42	24	17	Failed	Failed
WR-39			100	94	75	52	42	38	30	39	25	14	Failed	Failed
WR-40			100	96	85	61	43	37	31	39	24	15	Failed	Failed

Table E5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing							Atterberg Test			Otta Seal Specifications	
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
WR-41	100	99	90	57	45	37	30	38	25	13	Failed	Failed
WR-42	100	91	70	51	42	36	25	34	24	10	Failed	Passed
WR-43	97	96	86	48	37	32	24	34	23	11	Failed	Failed
WR-44	98	97	85	51	40	35	31	44	26	18	Failed	Failed
WR-45	100	93	75	49	40	37	35	58	35	24	Failed	Failed
WR-46	100	91	66	40	28	29	26	50	32	18	Failed	Failed
WR-47	100	94	72	45	38	34	26	40	25	15	Failed	Failed
WR-48	100	89	69	42	31	27	23	39	25	14	Failed	Failed
WR-49	100	92	67	45	34	27	25	43	28	16	Failed	Failed
WR-50					30	27	19	40	25	15	Failed	Failed
WR-51					34	27	16	28	19	9	Failed	Passed
WR-52					27	22	20	39	32	7	Failed	Passed
WR-53					34	26	14	34	21	14	Failed	Failed
WR-54					22	17	13	25	17	8	Failed	Passed
WR-55					20	14	11	38	22	15	Failed	Failed
WR-56					37	29	18	24	16	8	Failed	Passed
WR-57					26	22	18	21	14	7	Failed	Passed
WR-58					24	19	14	30	19	12	Failed	Failed
WR-59					45	38	32	45	23	22	Failed	Failed
WR-60					33	24	19	35	23	12	Failed	Failed

Table E5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing							Atterberg Test			Otta Seal Specifications	
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
WR-61					24	18	15	35	19	16	Failed	Failed
WR-62					32	16	12	30	20	10	Failed	Passed
WR-63					29	23	20	44	26	18	Failed	Failed
WR-64					38	32	28	44	30	14	Failed	Failed
WR-65					31	26	22	43	29	14	Failed	Failed
WR-66					26	18	11	23	18	5	Failed	Passed
WR-67					29	22	18	36	21	15	Failed	Failed
WR-68					44	38	28	39	23	16	Failed	Failed
WR-69					34	29	23	40	30	11	Failed	Failed
WR-70					33	26	16	23	13	10	Failed	Passed
WR-71					40	33	24	37	20	18	Failed	Failed
WR-72					22	16	12	32	19	13	Failed	Failed

Table E6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			Otta Seal Specifications	
	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
BAR-1	100	95	91.6	88	84	69.6	41.1	40.3	39.2	30	N/A	N/A	12	Failed	Passed
BAR-2	100	93	88.9	86	76	65.9	47.9	41.3	37.5	30	N/A	N/A	11	Failed	Passed
BAR-3	100	84	72.9	63	51	45	36.4	32.9	30.8	26.8	N/A	N/A	19	Failed	Failed
BAR-4	100	99	93.7	87	67	50.4	29.7	29.3	25.6	17	N/A	N/A	NP	Failed	Passed
BAR-5	100	97	93.9	85	63	45.4	21.3	17.3	16.3	10.2	N/A	N/A	7	Failed	Passed
BAR-6	100	100	100	98	90	74.7	37.2	28.2	24.9	12.6	N/A	N/A	NP	Failed	Passed
BAR-7	100	95	80.3	72	58	48.2	41.3	38.2	36.2	18.3	N/A	N/A	NP	Failed	Passed
BAR-8	100	74	58.6	54	47	43.7	39.4	37.8	33.4	14.6	N/A	N/A	NP	Failed	Passed
BAR-9	100	97	92.7	88	75	62	34.9	28.2	23.6	14.5	N/A	N/A	10.2	Failed	Failed
BAR-10	100	90	79.2	74	55	39	13	9.5	7.9	5.3	N/A	N/A	2.4	Failed	Passed
BAR-11	100	90	68	54	41	37.3	34.3	31.9	25.3	11	N/A	N/A	NP	Failed	Passed
BAR-12	95.6	89	83.4	77	67	55.8	35.2	27.2	21	15.6	N/A	N/A	16.2	Failed	Failed
BAR-13	100	93	92.1	91	77	63.3	34.6	26.4	22.9	19.8	N/A	N/A	19	Failed	Failed
BAR-14	100	87	77	66	51	35.9	18.3	14.9	13.1	10.9	N/A	N/A	11	Failed	Failed
BAR-15	100	97	92	88	76	63.8	50.1	46.9	43	29.8	N/A	N/A	15	Failed	Failed
BAR-16	100	96	92	84	70	55.3	52	51.2	45.1	28.6	N/A	N/A	16	Failed	Failed
BAR-17							27		19	16	33	17	15	Failed	Failed
BAR-18							22		14	10	19	14	5	Failed	Passed
BAR-19							37		27	23	35	16	19	Failed	Failed
BAR-20							28		21	18	45	25	20	Failed	Failed

Table E6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Otta Seal specifications

Sample Identification	Gradation			Atterberg limits			Otta Seal Specifications	
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. L %	P. I %	Grading	PI< 10
BAR-21	75	11	14	18	14	4	N/A	Passed
BAR-22	88	12	0	23	18	5	N/A	Passed
BAR-23	70	19	11	15	12	3	N/A	Passed

Table E7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Otta Seal Specifications

Sample Identification	Grading									Atterberg Test			Otta Seal Specifications	
	Percentage Passing													
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
ER-1	100		91.7	50	38	26.9	19.7	15.9	10.7	N/A	N/A	N/A	Failed	N/A
ER-2	100		86.7	50	37	26.5	19.5	15.75	12.3	N/A	N/A	N/A	Failed	N/A
ER-3	100		95.1	85	77	58	43.5	22.3	11	N/A	N/A	N/A	Failed	N/A
ER-4	98		91.4	76	63	52.5	46.2	28.2	21.4	N/A	N/A	16.3	Failed	Failed
ER-5	97		86.1	76	66	53.5	47.6	31.4	25.9	N/A	N/A	13.3	Failed	Failed
ER-6	100		93	78	64	53.4	46.6	28.9	23.9	N/A	N/A	19.7	Failed	Failed
ER-7	98		88.8	72	58	48.7	42.5	25.2	19.4	N/A	N/A	19.6	Failed	Failed
ER-8	100		100	100	76	56.1	40.5	31.3	22.1	N/A	N/A	N/A	Failed	N/A
ER-9	100		100	100	88	70	42	34	30	N/A	N/A	N/A	Failed	N/A
ER-10	100		100	100	90	72	53	19	12	N/A	N/A	N/A	Failed	N/A
ER-11			93	86	69	50	41	26	18	25	18	7	Failed	Passed
ER-12			98	94	86	69	39	18	9	21	15	6	Failed	Passed
ER-13			92	88	76	60	43	26	16	25	14	11	Failed	Failed
ER-14			95	83	67	45	27	17	10	23	17	6	Failed	Passed
ER-15			94	80	64	49	29	15	7	26	15	11	Failed	Failed
ER-16			95	85	72	57	42	21	9	23	11	12	Failed	Failed
ER-17	100	99		96	81	54	38	30	15	45	23	22	Failed	Failed
ER-18	100	100		100	87	57	38	30	15	47	23	24	Failed	Failed
ER-19	100	100		98	86	55	37	28	12	43	22	21	Failed	Failed
ER-20	100	95	86	68	45	37	31	25	13	28	16	12	Failed	Failed

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Table E7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			Otta Seal Specifications	
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI< 10
ER-21	99	97	93	80	65	54	45	38	33	15	19	13	6	Failed	Passed
ER-22	98	94	88	72	61	50	42	38	31	16	25	15	10	Failed	Passed
ER-23	100	99	95	80	61	49	38	35	34	26	40	21	19	Failed	Failed
ER-24	100	99	96	81	61	46	35	29	22	14	37	21	16	Failed	Failed

Table E8: Grading and plastic limits of natural gravels in the Central Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			Otta Seal Specifications	
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI< 10
CR-1		100	92	85	78	62	49	26	19	16	13	43.5	26.8	16.7	Failed	Failed
CR-2		100	89	81	74	62	55	41	33	23	15	25.9	15.7	10.2	Failed	Failed
CR-3		100	88	83	77	61	49	31	25	22	18	42.8	29.8	13	Failed	Failed
CR-4		100	89	82	76	65	57	44	40	28	17	22.8	15.4	7.4	Failed	Passed
CR-5		100	77	64	54	42	36	28	24	21	17	33.5	20.2	13.3	Failed	Failed
CR-6		100	92	82	75	64	55	35	26	21	16	33.7	21.7	12	Failed	Failed
CR-7		100	87	82	76	66	60	41	30	20	13	24.7	15.9	8.8	Failed	Passed
CR-8		100	78	69	62	52	47	38	33	29	23	32.1	20	12.1	Failed	Failed
CR-9		100	85	76	68	57	49	35	28	21	14	31.5	18.7	12.8	Failed	Failed
CR-10		100	91	90	78	68	62	48	38	31	23	38.9	20	18.9	Failed	Failed
CR-11		100	94	90	87	78	71	49	38	28	20	30.7	18.4	12.3	Failed	Failed
CR-12		100	92	90	86	78	72	60	51	41	34	38.9	22	16.9	Failed	Failed
CR-13	100	100	98		61		31	24		17	13	N/A	N/A	9	Failed	Passed
CR-14	100	100	97		72		50	37		29	24	N/A	N/A	15	Failed	Failed
CR-15	100	95	74		48		33	25		18	14	N/A	N/A	14	Failed	Failed
CR-16	100	100	91		75		49	34		15	9	N/A	N/A	8	Failed	Passed
CR-17	100	100	87		78		53	38		16	7	N/A	N/A	4	Failed	Passed
CR-18	100	97	92		83		62	34		13	9	N/A	N/A	7	Failed	Passed
CR-19	100	100	96		87		67	44		21	15	N/A	N/A	11	Failed	Failed
CR-20	100	100	89		70		53	41		29.5	18	N/A	N/A	8.6	Failed	Passed

Table E8: Grading and plastic limits of natural gravels in the Central Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			Otta Seal Specifications	
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤ 10
CR-21		100	98	81	64	50	36	18	17	N/A	N/A	14	Failed	Failed
CR-22		100	98	86	76	58	45	25	24	N/A	N/A	9	Failed	Passed
CR-23		100	100	100	93	79	60	17.5	31.5	N/A	N/A	11.8	Failed	Failed
CR-24		100	100	100	89	66	54	37.75	21.5	N/A	N/A	19.1	Failed	Failed
CR-25		100	100	100	81	58	39	22.9	17	N/A	N/A	12.9	Failed	Failed
CR-26		100	100	94	88	72	52	31.5	8.5	N/A	N/A	4.2	Failed	Passed
CR-27	100		95	91	84	69	43	21	11	23	12	11	Failed	Failed
CR-28	99		95	90	83	70	40	25	15	35	17	19	Failed	Failed
CR-29	100		96	91	81	69	43	22	15	29	14	15	Failed	Failed
CR-30	98		95	91	83	67	40	20	9	23	10	13	Failed	Failed
CR-31	99		96	94	86	65	35	20	10	25	11	14	Failed	Failed
CR-32	100		95	89	78	73	39	22	9	20	10	10	Failed	Passed
CR-33	100		99	97	90	76	42	21	12	27	12	15	Failed	Failed
CR-34	100		97	94	85	62	27	14	5	11	5	6	Failed	Passed
CR-35	100		98	95	83	62	38	19	9	17	9	8	Failed	Passed
CR-36	100		97	93	88	73	44	26	12	10	5	5	Failed	Passed
CR-37	99		95	86	76	57	32	20	10	34	13	21	Failed	Failed
CR-38	99		93	87	78	52	44	36	29	61	24	37	Failed	Failed
CR-39	100	100	97	91	85	70	30	12	7	28	14	14	Failed	Failed
CR-40	100		97	92	82	64	46	37	35	65	29	36	Failed	Failed

Table E8: Grading and plastic limits of natural gravels in the Central Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			Otta Seal Specifications	
	75 mm	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI< 10
CR-41	100		93	89	82		67	47		24	20	28	12	16	Failed	Failed
CR-42	100	99	97	93	88		68	48	40	38	30	43	23	20	Failed	Failed
CR-43	100	100	96	85	70		57	38	34	30	21	33	17	18	Failed	Failed
CR-44	100	100	98	94	87		66	34	31	30	26	53	28	25	Failed	Failed
CR-45	100	100	98	92	64		46	45	36	34	25	42	21	19	Failed	Failed
CR-46	100	96	91	78	47		36	32	30	26	18	30	16	14	Failed	Failed
CR-47	100	100	92	84	56		38	26	23	22	20	62	27	35	Failed	Failed
CR-48	100	100	98	92	80		56	34	28	27	22	37	23	14	Failed	Failed
CR-49	100	100	96	85	62		46	39	37	33	26	44	21	23	Failed	Failed
CR-50	100	84	80	70	53		45	33	29	28	23	43	27	16	Failed	Failed
CR-51	100	100	96	86	66		46	31	23	20	15	42	23	19	Failed	Failed
CR-52	100	83	80	67	55		42	33	29	27	20	41	21	20	Failed	Failed
CR-53	100	99	96	88	63		40	21	13	8	1	36	19	16	Failed	Failed
CR-54	100	100	94	84	69		51	37	27	27	11	34	13	11	Failed	Failed
CR-55		100	98	90	69	59	50	33	24	16	5	N/A	N/A	N/A	Failed	N/A
CR-56		100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	Failed	N/A

Table E9: Grading and plastic limits of natural gravels in the Volta Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI≤ 10
VR-1	100	98	85		58	44		25	14	N/A	N/A	8.8	Failed	Passed
VR-2	100	96	81		29	19		11	9	N/A	N/A	8.8	Failed	Passed
VR-3	100	92	74		52	41		26	14	N/A	N/A	7	Failed	Passed
VR-4	100	100	93		64	56		28	22	N/A	N/A	14.7	Failed	Failed
VR-5	100	100	65		44	25		17	10	N/A	N/A	6.1	Failed	Passed
VR-6	100	100	72		52	38		21	13	N/A	N/A	4.3	Failed	Passed
VR-7	100	100	93		74	79		52	13	N/A	N/A	4.3	Failed	Passed
VR-8	100	100	70		52.5	35		23	18	N/A	N/A	9	Failed	Passed
VR-9	100	100	87		61	43		28	22	N/A	N/A	7.7	Failed	Passed
VR-10	100	96	84		60	51		29	16	N/A	N/A	6.2	Failed	Passed
VR-11	100	91	78		57	53		26	14	N/A	N/A	7.4	Failed	Passed
VR-12		99	98	63	29	24	22		14	39	22	17	Failed	Failed
VR-13			130	69	33	26	23		14	45	24	21	Failed	Failed
VR-14		100	99	71	38	20	17		8	40	25	15	Failed	Failed
VR-15			100	81	44	25	17		14	33	18	15	Failed	Failed
VR-16		100	98	86	47	24	20		12	28	17	11	Failed	Failed
VR-17		100	97	87	56	38	32		18	23	15	8	Failed	Passed
VR-18		100	98	86	57	35	33		14	21	14	7	Failed	Passed
VR-19		100	97	86	34	17	12		4	25	19	6	Failed	Passed
VR-20		100		73	36	16	12		6	28	18	10	Failed	Passed

Table E9: Grading and plastic limits of natural gravels in the Volta Region compared to Otta Seal Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	Otta Seal Specifications: Grading	PI< 10
VR-21	100		87	72	46	33	26		12	33	16	17	Failed	Failed
VR-22		100	99	77	48	32	27		18	46	26	20	Failed	Failed
VR-23			100	69	33	23	20		13	38	22	16	Failed	Failed
VR-24		99	98	63	29	21	17		12	39	21	18	Failed	Failed
VR-25			93			41		35	25	23	13	10	Failed	Passed
VR-26			100			43		27	7	21	20	1	Failed	Passed
VR-27			100			51		32	20	20	14	6	Failed	Passed
VR-28			100			43		34	23	23	17	6	Failed	Passed
VR-29			100			28		23	15	19	15	4	Failed	Passed
VR-30			99			33		26	21	20	14	6	Failed	Passed
VR-31			99			40		28	22	28	20	8	Failed	Passed
VR-32			99			36		25	20	27	20	7	Failed	Passed
VR-33			99			43		28	19	17	14	3	Failed	Passed
VR-34			99			37		33	24	19	13	6	Failed	Passed
VR-35			99			31		25	21	21	14	7	Failed	Passed
VR-36			99			27		22	16	20	4	16	Failed	Failed
VR-37			100			29		25	19	19	16	3	Failed	Passed
VR-38			100			49		31	21	19	16	3	Failed	Passed
VR-39			99			42		37	25	20	15	5	Failed	Passed

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Table E10: Grading and plastic limits of natural gravels in the Greater Accra Region compared to Otta Seal specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			Otta Seal Specifications	
	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	Grading	PI≤10
GAR-1	100		98	79		59	41	33	27	18	22	12	10	Failed	Passed
GAR-2	100		100	91		62	39	31	25	14	20	14	6	Failed	Passed
GAR-3	100		100	81		57	37	32	28	16	19	12	7	Failed	Passed
GAR-4	100		93	70		54	46	43	38	22	18	11	7	Failed	Passed
GAR-5	100		99	97		81	52	41	33	20	29	16	13	Failed	Failed
GAR-6	100		100	96		68	41	33	26	16	23	12	11	Failed	Failed
GAR-7	100		100	91		72	39	28	21	14	24	13	11	Failed	Failed
GAR-8	100		100	95		77	48	37	31	19	24	11	13	Failed	Failed
GAR-9	100		98	83		58	43	39	33	17	22	9	13	Failed	Failed
GAR-10	100		100	89		70	37	27	19	11	20	10	10	Failed	Passed
GAR-11	99		91	77		58	36	29	22	14	28	15	13	Failed	Failed
GAR-12	100		98	92		72	48	33	26	17	22	12	10	Failed	Passed
GAR-13	100		95	87		68	42	30	24	15	24	13	11	Failed	Failed
GAR-14	100		96	80		59	38	32	24	15	19	11	8	Failed	Passed
GAR-15	100		97	87		67	38	28	21	12	24	14	10	Failed	Passed
GAR-16		98	85	67	53	46	34	24	15	8	N/A	N/A	N/A	Failed	N/A
GAR-17	100	98	92	68	51	44	34	30	25	15	N/A	N/A	N/A	Failed	N/A
GAR-18			100	96	83	74	52	42	33	19	N/A	N/A	N/A	Failed	N/A
GAR-19	100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	Failed	N/A
GAR-20	100	97	87	69	54	45	35	31	23	12	N/A	N/A	N/A	Failed	N/A
GAR-21		97	92	83		68	43		17	9	19	15	4	Failed	Passed

APPENDIX F:
COMPARING GRADING, CBR AND ATTERBERG LIMITS OF NATURAL GRAVELS WITH MOT G30 SUBBASE REQUIREMENTS

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Table F1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
NR-1	100	90	83	69	59	34	23	17	11	21.7	13.3	8.4	N/A				N/A
NR-2	100	93	87	68	49	23	15	13	11	24.3	15.7	8.6	N/A				N/A
NR-3	100	92	86	66	46	20	14	12	10	21.8	13.6	8.2	N/A	Passed	Passed	Passed	N/A
NR-4	100	91	82	63	51	30	25	20	17	22.6	15.1	7.5	N/A	Passed	Passed	Passed	N/A
NR-5	100	89	76	55	45	32	28	27	25	27.2	15.4	11.8	N/A	Failed	Passed	Passed	N/A
NR-6	100	98	91	77	65	44	34	29	23	26.3	15.4	10.9	N/A	Passed	Passed	Passed	N/A
NR-7	100	100	96	80	59	26	20	18	13	19.6	13.2	6.4	N/A	Passed	Passed	Passed	N/A
NR-8	100	97	90	77	64	33	21	17	14	33.5	20.7	12.8	N/A	Failed	Passed	Passed	N/A
NR-9	100		78		41.1	22.3	14.6	12.4	10.4	N/A	N/A	12	N/A	Failed	Passed	Passed	N/A
NR-10	100		95		58.5	33.8	23.9	20.2	16.8	N/A	N/A	11.1	N/A	Failed	Passed	Passed	N/A
NR-11	100		92		57.7	30.2	19.5	16.7	13	N/A	N/A	18.3	N/A	Passed	Passed	N/A	N/A
NR-12	100		90		63.7	46.8	42	38.8	25.6	N/A	N/A	17.3	N/A	Failed	Passed	N/A	N/A
NR-13	100		96		70.6	34.2	25.6	23.2	15.5	N/A	N/A	23.7	N/A	Failed	Failed	N/A	N/A
NR-14	100		87		53.6	27.2	17.7	13.9	9	N/A	N/A	13.3	N/A	Failed	Failed	N/A	N/A
NR-15	100		83		53.2	33	27.5	25.5	22.6	N/A	N/A	14.3	N/A	Failed	Failed	N/A	N/A
NR-16	100		99.5		88.4	40	24.2	21.5	14.4	N/A	N/A	12.3	N/A	Passed	Passed	N/A	N/A
NR-17	100		94		56.9	34.4	26.8	24	13.9	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
NR-18	100		97		70.9	33.6	24.8	23.4	19.4	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
NR-19	100		64		29.7	17.7	14	11	10.9	N/A	N/A	14.5	N/A	Failed	Passed	N/A	N/A
NR-20	100		99		93	63.2	47.2	38.1	33	N/A	N/A	16.1	N/A	Failed	Passed	N/A	N/A

Table F1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
NR-21		100	100	85	47	24	18	16	12	N/A	N/A	16.4	N/A	Passed	Failed	N/A	N/A
NR-22		100	100	99	73	38	29	25	20	N/A	N/A	14	N/A	Failed	Passed	N/A	N/A
NR-23		100	100	97	73	39	30	28	19	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
NR-24		100	100	90	56	31	30	30	21	N/A	N/A	7.7	N/A	Passed	Passed	N/A	N/A
NR-25		100	100	97	57	33	27	26	19	N/A	N/A	3.9	N/A	Failed	Passed	N/A	N/A
NR-26		100	100	66	43	30	26	24	19	N/A	N/A	10.3	N/A	Passed	Passed	N/A	N/A
NR-27		100	100	94	56	31	25	24	17	N/A	N/A	14.3	N/A	Failed	Passed	N/A	N/A
NR-28	100	92	81	64	46	34		30	19	17.2	12.3	4.9	85	Passed	Passed	Passed	Passed
NR-29	100	91	78	53	36	31		29	14	17.8	12.3	5.5	75	Passed	Passed	Passed	Passed
NR-30		100	82	63	45	37		32	14	14.8	10.1	4.7	56	Passed	Passed	Passed	Passed
NR-31	100	98	84	63	42	30		26	13	17.8	10.6	7.2	80	Passed	Passed	Passed	Passed
NR-32	100	97	91	84	76	45		38	20	17.4	12.8	4.6	42	Failed	Passed	Passed	Passed
NR-33	100	95	92	79	50	32		20	6	17.4	12.7	4.7	45	Passed	Passed	Passed	Passed
NR-34	100	95	91	80	48	25		18	7	18.2	12.5	5.7	55	Passed	Passed	Passed	Passed
NR-35	100	96	90	78	60	40		32	23	17	13.5	3.5	32	Passed	Passed	Passed	Passed
NR-36		100	95	81	50	29		25	12	NP	NP	NP	35	Passed	Passed	Passed	Passed
NR-37	100	96	79	68	46	27		19	7	26.6	18	8.6	55	Passed	Passed	Passed	Passed
NR-38		100	91	84	64	45		36	14	21.2	14.7	6.5	50	Failed	Passed	Passed	Passed
NR-39	100	89	78	54	38	25		20	15	24.6	18.8	5.8	51	Passed	Passed	Passed	Passed
NR-40	100	96	89	68	40	25		11	5	22.2	17.2	5	65	Passed	Passed	Passed	Passed

Table F1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 16	LL≤ 35	CBR≥ 30
NR-41	100	97	92	86	57	33		25	19	21.8	14.9	6.9	23	Passed	Passed	Passed	Failed
NR-42	100	93	83	72	54	29		21	17	23.8	18.2	5.6	20	Passed	Passed	Passed	Failed
NR-43	100	95	89	76	60	43		29	13	19.8	13.8	6	33	Passed	Passed	Passed	Passed
NR-44		100	93	90	75	48		34	11	19.4	13.9	5.5	46	Passed	Passed	Passed	Passed
NR-45	100	97	92	80	59	37		22	9	17.8	13.4	4.4	60	Passed	Passed	Passed	Passed
NR-46		100	85	65	42	31	23	17	7	19	14	5	95	Passed	Passed	Passed	Passed
NR-47		100	90	70	41	24	20	18	14	18	13	5	69	Passed	Passed	Passed	Passed
NR-48		100	95	75	66	43	41	39	32	57	25	31	50	Failed	Failed	Failed	Passed
NR-49		100	91	70	40	20	14	15	10	19	13	6	90	Failed	Passed	Passed	Passed
NR-50		100	89	74	49	29	23	21	11	NP	NP	NP	50	Passed	Passed	Passed	Passed
NR-51		100	94	70	31	16	13	9	3	NP	NP	NP	50	Failed	Passed	Passed	Passed
NR-52		100	98	79	49	24	23	14	9	NP	NP	NP	118	Passed	Passed	Passed	Passed
NR-53		100	99	84	41	22	18	12	5	NP	NP	NP	125	Passed	Passed	Passed	Passed
NR-54		100	100	90	56	36	29	20	11	NP	NP	NP	N/A	Passed	Passed	Passed	N/A
NR-55		100	100	89	57	33	27	19	7	NP	NP	NP	N/A	Passed	Passed	Passed	N/A
NR-56		100	100	88	45	24	20	14	7	NP	NP	NP	200	Passed	Passed	Passed	Passed
NR-57		100	94	69	37	23	28	16	5	NP	NP	NP	32	Passed	Passed	Passed	Passed
NR-58		100	90	76	52	36	28	13	8	NP	NP	NP	44	Passed	Passed	Passed	Passed
NR-59		100	83	59	43	27	21	19	13	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-60		100	85	67	42	29	23	17	7	NP	NP	NP	101	Passed	Passed	Passed	Passed

Table F1: Grading, CBR and Atterberg's limits of natural gravels in the Northern compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 16	LL≤ 35	CBR≥ 30
NR-41	100	83	62	48	40	29	21	11	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-42	100	88	68	41	27	22	16	11	NP	NP	NP	60	Passed	Passed	Passed	Passed
NR-43	100	89	55	33	25	22	19	11	NP	NP	NP	97	Passed	Passed	Passed	Passed

Sample Identification	Gradation: Gravel %	Sand %	Silt+Cla y %	Atterberg limits: L. L. %	P. I. %	P. I. %	CBR at 98%	Subbase specification: Grading	PI≤ 16	LL≤ 35	CBR≥ 30
NR-44	57	15	28	20	14	6	70	N/A	Passed	Passed	Passed
NR-45	81	7	12	20	15	5	49	N/A	Passed	Passed	Passed
NR-46	80	5	15	21	14	7	66	N/A	Passed	Passed	Passed
NR-47	76	5	19	29	19	10	27	N/A	Passed	Passed	Failed
NR-48	77	9	14	16	13	3	75	N/A	Passed	Passed	Passed

Table F2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR> 30
UWR-1		100	94	86	61	38	33		16	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 2		100	94	63	35	22	17		15	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 3		100	100	87	47	34	29		18	N/A	N/A	14	N/A	Passed	Passed	N/A	N/A
UWR- 4		100	89	69	41	27	22		10	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 5		100	87	61	37	30	23		11	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 6		100	98	88	60	39	32		12	N/A	N/A	9.1	N/A	Passed	Passed	N/A	N/A
UWR- 7		92	94	80	55	41	33		19	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
UWR- 8		100	97	90	69	41	36		11	N/A	N/A	7	N/A	Passed	Passed	N/A	N/A
UWR- 9		100	95	82	58	41	33		13	N/A	N/A	6	N/A	Passed	Passed	N/A	N/A
UWR -10		100	96	87	63	44	30		19	N/A	N/A	10	N/A	Passed	Passed	N/A	N/A
UWR -11		96	95	76	47	33	26		10	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR -12		100	100	81	52	36	34		8	N/A	N/A	6	N/A	Passed	Passed	N/A	N/A
UWR -13		81	76	57	40	31	29		9	N/A	N/A	4	N/A	Passed	Passed	N/A	N/A
UWR -14		100	96	87	56	36	29		13	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR -15		100	95	86	61	34	31		12	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR -16		100	100	93	70	54	42		19	N/A	N/A	5.7	N/A	Failed	Passed	N/A	N/A
UWR -17	100	99	82	77	55	36		20	8	20.6	13.1	7.5	45	Failed	Passed	Passed	Passed
UWR -18	100	99	97	90	65	35		22	13	34.6	20.5	14.1	75	Passed	Passed	Passed	Passed
UWR -19		100	99	94	70	48		28	13	21.2	17	4.2	47	Passed	Passed	Passed	Passed
UWR -20	100	83	86	76	50	29		20	8	23	18.5	4.5	60	Passed	Passed	Passed	Passed

Table F2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR> 30
UWR -21	100	86	65	48	31	21	14	7	26.5	17.1	9.4	50	Passed	Passed	Passed	Passed
UWR -22			100	87	55	43	25	13	18.8	14.1	4.7	56	Passed	Passed	Passed	Passed
UWR -23		100	99	97	80	49	25	8	21	14.5	6.5	80	Passed	Passed	Passed	Passed
UWR -24		100	95	89	63	37	21	10	21.8	16.6	5.2	40	Passed	Passed	Passed	Passed
UWR -25	100	100	95	82	63	38	31	19	26.1	16.9	9.2	38	Passed	Passed	Passed	Passed
UWR -26	100	99	90	79	62	45	26	12	20	14.1	5.9	45	Passed	Passed	Passed	Passed
UWR -27	100	98	86	61	40	23	15	6	17.6	12.7	4.9	60	Passed	Passed	Passed	Passed
UWR -28	100	95	82	69	49	30	21	7	19.1	14.1	5	60	Passed	Passed	Passed	Passed
UWR -29			100	94	70	41	26	13	26.2	14.3	11.9	45	Passed	Passed	Passed	Passed
UWR -30		100	98	82	51	32	26	13	27.3	15.3	12	55	Passed	Passed	Passed	Passed
UWR -31		100	100	97	82	61	36	19	24.7	15.7	9	45	Passed	Passed	Passed	Passed
UWR -32		100	98	89	65	43	29	11	23.1	17.2	5.9	70	Passed	Passed	Passed	Passed
UWR -33		100	98	85	58	37	28	13	20.5	12.6	7.9	60	Failed	Passed	Passed	Passed
UWR -34	100	99	94	71	44	33	23	11	20.9	15.3	5.6	70	Failed	Passed	Passed	Passed
UWR -35		100	99	95	79	43	29	13	17.6	11.9	5.7	78	Failed	Passed	Passed	Passed
UWR -36	100	99	83	72	55	39	29	15	22.4	15.2	7.2	67	Passed	Passed	Passed	Passed
UWR -37	100	99	91	72	57	40	31	19	28.7	16.9	11.8	45	Passed	Passed	Passed	Passed
UWR -38		100	99	82	67	43	37	26	21.5	16.5	5	55	Failed	Passed	Passed	Passed
UWR -39		100	95	83	62	42	30	22	23.6	18.5	5.1	55	Failed	Passed	Passed	Passed
UWR -40			88			46	24	13	NP	NP	NP	100	Passed	Passed	Passed	Passed

Table F2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing							Atterberg Test			CBR at 98%	Subbase Specifications			
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
UWR -41					52	33	17	24	19	5	30	Passed	Passed	Passed	Passed
UWR -42					35	25	16	23	19	4	95	Passed	Passed	Passed	Passed
UWR -43		98			34	17	13	26	25	1	42	Passed	Passed	Passed	Passed
UWR -44		97			39	25	18	24	19	4	23	Passed	Passed	Passed	Failed
UWR -45		100			42	27	17	24	20	4	50	Passed	Passed	Passed	Passed
UWR -46		82			21	15	14	32	22	10	73	Passed	Passed	Passed	Passed
UWR -47					40	23	18	32	16	16	18	Failed	Passed	Passed	Failed
UWR -48		100			39	23	11	32	16	16	67	Passed	Passed	Passed	Passed
UWR -49		78			42	32	16	21	15	6	48	Passed	Passed	Passed	Passed
UWR -50		96			46	28	19	34	19	15	67	Passed	Passed	Passed	Passed
UWR -51		82			39	26	15	26	17	9	42	Failed	Passed	Passed	Passed
UWR -52		89			21	15	13	29	19	10	70	Passed	Passed	Passed	Passed
UWR -53		94			39	20	8	23	19	4	50	Passed	Passed	Passed	Passed
UWR -54		95			42	32	29	18	16	2	28	Failed	Passed	Passed	Failed
UWR -55		100			68	49	30	27	19	8	37	Failed	Passed	Passed	Passed
UWR -56		99			56	35	18	20	19	1	53	Passed	Passed	Passed	Passed
UWR -57		83			21	16	6	NP	NP	NP	128	Passed	Passed	Passed	Passed

Table F3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
UER-1	100	100	99	94	91	76	57		15	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-2	100	100	92	81	75	66	57		20	N/A	N/A	17	N/A	Failed	Failed	N/A	N/A
UER-3	100	100	98	95	94	85	72		19	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-4	93	93	90	88	84	75	66		22	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
UER-5	100	100	99	90	81	72	60		18	N/A	N/A	18	N/A	Failed	Failed	N/A	N/A
UER-6	100	100	96	95	94	82	58		21	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-7	100	100	97	89	81	70	61		16	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
UER-8	100	100	95	91	88	72	63		16	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-9	100	100	93	91	85	73	52		18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-10	100	100	94	90	88	80	75		19	N/A	N/A	16	N/A	Failed	Passed	N/A	N/A
UER-11			79				24	13	7	NP	NP	NP	120	Passed	Passed	Passed	Passed
UER-12			93				40	22	14	22	15	7	60	Failed	Passed	Passed	Passed
UER-13		100				68	36	23		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-14		100				70	52	34		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-15		100				57	32	19		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-16		100				63	36	21		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-17		100				44	27	15		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

Table F3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Subbase specifications

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Subbase specification			
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. I %	P. L %		Grading	PI< 14	LL< 30	CBR> 40
UER-18	75	9	16	21	14	7	21	N/A	Passed	Passed	Failed
UER-19	61	21	18	21	14	7	33	N/A	Passed	Passed	Failed

Table F4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading											Atterberg Test			CBR at 98%	Subbase Specifications			
	Percentage Passing																		
	53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
AR-1	100	100	89	58	45	38	33	24	23	22	22	44	21	23	N/A	Passed	Failed	Failed	N/A
AR-2	100	100	82	59	49	43	33	27	21	15	18	35	19	15	N/A	Passed	Passed	Passed	N/A
AR-3	100	100	75	57	52	47	41	32	28	21	19	36	17	19	N/A	Passed	Failed	Failed	N/A
AR-4	100	100	78	59	47	37	31	21	17	15	14	33	17	16	N/A	Passed	Passed	Passed	N/A
AR-5	100	100	99	94	81	72	57	32	24	21	18	31	16	15	N/A	Passed	Passed	Passed	N/A
AR-6	100	100	98	91	80	65	54	37	33	28	15	37	20	17	N/A	Passed	Failed	Failed	N/A
AR-7	100	100	92	87	81	69	57	39	33	31	26	40	22	19	N/A	Failed	Failed	Failed	N/A
AR-8	-	-	-	-	-	-	-	-	-	-	-	44	20	24	N/A	N/A	Failed	Failed	N/A
AR-9	100	92	77	66	55	38	29	21	19	18	16	52	29	24	N/A	Failed	Failed	Failed	N/A
AR-10	100	100	100	98	89	64	48	28	24	21	15	52	25	26	N/A	Passed	Failed	Failed	N/A
AR-11	100	100	99	94	89	75	62	41	35	31	25	49	26	23	N/A	Failed	Failed	Failed	N/A
AR-12	100	100	100	72	60	48	36	24	20	14	11	24	14	9	N/A	Failed	Passed	Passed	N/A
AR-13	100	100	91	85	75	54	42	23	18	15	10	43	26	17	N/A	Passed	Failed	Failed	N/A
AR-14	100	100	97	90	84	73	61	38	33	30	28	53	25	28	N/A	Passed	Failed	Failed	N/A
AR-15	93	85	70	55	42	34	30	23	21	18	14	38	20	18	N/A	Failed	Failed	Failed	N/A
AR-16	100	97	90	86	79	74	70	57	42	29	23	46	22	24	N/A	Passed	Failed	Failed	N/A
AR-17	100	95	83	76	68	60	52	38	31	28	24	42	21	21	N/A	Failed	Failed	Failed	N/A
AR-18			92					35		24	21	28	17	11	38	Passed	Passed	Passed	Passed
AR-19			90					24		18	12	22	17	5	38	Passed	Passed	Passed	Passed
AR-20			92					18		12	9	25	18	7	98	Failed	Passed	Passed	Passed

Table F4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading							Atterberg Test			CBR at 98%	Subbase Specifications			
	Percentage Passing														
	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
AR-21		89			72	17	14	34	15	19	76	Failed	Failed	Passed	Passed
AR-22		92			45	21	18	36	22	12	35	Passed	Passed	Failed	Passed
AR-23		91			24	15	10	25	17	8	78	Passed	Passed	Passed	Passed
AR-24		94			50	28	16	24	16	8	56	Passed	Passed	Passed	Passed
AR-25		96			35	20	11	32	24	8	99	Passed	Passed	Passed	Passed
AR-26		98			36	20	13	27	15	12	60	Passed	Passed	Passed	Passed
AR-27		94			15	11	8	23	17	6	94	Failed	Passed	Passed	Passed
AR-28		91			12	7	5	23	16	7	138	Failed	Passed	Passed	Passed
AR-29		92			26	22	19	32	25	7	18	Passed	Passed	Passed	Failed
AR-30		93			37	27	23	49	20	29	40	Passed	Failed	Failed	Passed
AR-31		87			45	17	9	36	19	17	40	Failed	Failed	Failed	Passed
AR-32		89			36	25	19	39	22	16	50	Passed	Passed	Failed	Passed
AR-33		94			39	31	25	33	20	12	35	Passed	Passed	Passed	Passed
AR-34		70			26	19	14	42	19	23	35	Failed	Failed	Failed	Passed
AR-35		87			34	25	19	17	9	8	90	Failed	Passed	Passed	Passed
AR-36		95			42	25	16	28	16	12	100	Passed	Passed	Passed	Passed
AR-37		85			18	13	9	19	10	9	89	Passed	Passed	Passed	Passed
AR-38		84			22	16	11	18	9	9	64	Failed	Passed	Passed	Passed
AR-39		86			20	14	10	23	15	8	95	Failed	Passed	Passed	Passed
AR-40		72			30	23	20	43	23	20	35	Failed	Failed	Failed	Passed

Table F4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading							Atterberg Test			CBR at 95%	Subbase Specifications			
	Percentage Passing														
	75 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL< 35	CBR> 30
AR-41		69			30	25	21	37	21	16	40	Failed	Passed	Failed	Passed
AR-42		90			34	19	14	27	16	11	60	Failed	Passed	Passed	Passed
AR-43		71			31	24	23	36	19	17	47	Passed	Failed	Failed	Passed
AR-44		88			43	16	11	29	16	13	60	Failed	Passed	Passed	Passed
AR-45		89			27	19	13	20	11	9	65	Passed	Passed	Passed	Passed
AR-46		90			29	21	14	27	10	17	45	Passed	Failed	Passed	Passed
AR-47		90			38	29	19	23	12	11	80	Passed	Passed	Passed	Passed
AR-48		90			37	27	19	30	16	14	80	Passed	Passed	Passed	Passed
AR-49		90			34	22	14	23	11	12	87	Passed	Passed	Passed	Passed
AR-50		84			15	14	9	17	9	8	82	Passed	Failed	Passed	Passed
AR-51		90			36	29	21	39	23	16	40	Passed	Passed	Failed	Passed
AR-52		84			20	14	10	24	14	10	95	Passed	Passed	Passed	Passed
AR-53		86			20	15	11	24	14	10	100	Failed	Passed	Passed	Passed
AR-54		86			31	24	10	33	19	12	60	Failed	Passed	Passed	Passed
AR-55		96			26	21	16	35	20	19	60	Passed	Failed	Failed	Passed
AR-56		94			22	14	9	23	11	12	100	Passed	Passed	Passed	Passed
AR-57		87			25	17	11	21	10	11	82	Failed	Passed	Passed	Passed
AR-58		98			37	26	18	28	16	12	47	Passed	Passed	Passed	Passed
AR-59		84			19	14	9	19	10	9	75	Passed	Passed	Passed	Passed
AR-60		86			18	13	10	22	12	10	93	Failed	Passed	Passed	Passed

Table F4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Subbase specifications

Sample Identification	Grading									Atterberg Test			CBR at 95%	Subbase Specifications			
	Percentage Passing																
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL< 35	CBR> 30
AR-61				88			28	18	14	34	17	17	98	Failed	Failed	Passed	Passed
AR-62				91			26	17	9	23	11	12	52	Passed	Passed	Passed	Passed
AR-63				88			22	22	14	24	12	12	100	Passed	Passed	Passed	Passed
AR-64	100		100	100	95	75	56	40	27	38	18	20	75	Passed	Failed	Failed	Passed
AR-65	100		100	92	86	70	49	29	18	28	17	11	57	Failed	Passed	Passed	Passed
AR-66	100		100	91	81	61	46	29	17	30	18	12	50	Passed	Passed	Passed	Passed
AR-67				100			43	31	26	46	12	34	55	Passed	Failed	Failed	Passed

Sample Identification	Gradation			Atterberg Limits			CBR at 98%	Subbase specification			
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. I. %	P. I. %		Grading	PI≤ 16	LL< 35	CBR> 30
AR-68	81	10	9	N/A	N/A	N/A	59	N/A	N/A	N/A	Passed
AR-69	88	6	6	N/A	N/A	N/A	100	N/A	N/A	N/A	Passed
AR-70	52	16	32	N/A	N/A	N/A	42	N/A	N/A	N/A	Passed
AR-71	65	19	6	N/A	N/A	N/A	66	N/A	N/A	N/A	Passed
AR-72	56	24	20	N/A	N/A	N/A	95	N/A	N/A	N/A	Passed
AR-73	82	10	8	N/A	N/A	N/A	23	N/A	N/A	N/A	Failed
AR-74	59	20	21	N/A	N/A	N/A	96	N/A	N/A	N/A	Passed
AR-75	68	15	17	N/A	N/A	N/A	53	N/A	N/A	N/A	Passed

Table F5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Subbase Specifications			
	53	37.5	20	13.2	10	6.7	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
WR-1	100	94.6	85	76.9	69	53	46.8	32.6	29.8	25.9	20.3	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
WR-2	100	100	79	63	47	38	29.7	25.9	23.1	20.4	16.3	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
WR-3	100	100	88	80.3	73	64	54.1	38.2	30.4	27.6	18.9	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
WR-4	93	90	79	73	62	55	48	41	38	25	13	N/A	N/A	4.5	N/A	Passed	Passed	N/A	N/A
WR-5	100	95	88	85	80	74	68	54	47	31	19	N/A	N/A	12.2	N/A	Failed	Passed	N/A	N/A
WR-6	97	95	81	73	67	59	51	39	33	24	17	N/A	N/A	12.4	N/A	Passed	Passed	N/A	N/A
WR-7	100	100	85	80.9	77	64	51.4	29.8	27.3	24.7	19.6	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
WR-8	100	100	86	77.3	69	52	55.8	46.9	39.5	32	20.2	N/A	N/A	14.4	N/A	Passed	Passed	N/A	N/A
WR-9	100	100	95	89.9	85	74	62.8	44	41.5	38.9	36.1	N/A	N/A	22	N/A	Failed	Failed	N/A	N/A
WR-10	100	100	95	88.8	82	62	49	33.6	29	27.4	21	N/A	N/A	8.4	N/A	Passed	Passed	N/A	N/A
WR-11	98.8	96.3	90	86.2	82	75	67.4	36.4	28.2	18.6	12.7	N/A	N/A	2.8	N/A	Passed	Passed	N/A	N/A
WR-12	100	72.8	61	52.7	44	30	25.1	20.4	15.8	12.8	7.9	N/A	N/A	13	N/A	Failed	Passed	N/A	N/A
WR-13	100	98.3	84	65.8	54	41	38	27.1	24.2	19.9	16	N/A	N/A	18.5	N/A	Passed	Failed	N/A	N/A
WR14	100	100	91	85	78	65	59.8	44.8	36.5	25.5	17.7	N/A	N/A	9.9	N/A	Passed	Passed	N/A	N/A
WR-15	97	91	85	77.4	67	53	47	31.6	28.4	21.7	16.7	N/A	N/A	8.5	N/A	Passed	Passed	N/A	N/A
WR-16	69.4	61.6	51	47	42	33	25.5	20	16.5	13.6	11	N/A	N/A	16	N/A	Failed	Passed	N/A	N/A
WR-17	100	97.5	96	90.4	83	68	55.5	37.3	31.2	28.7	22	N/A	N/A	13.5	N/A	Passed	Passed	N/A	N/A
WR-18	96.3	94.7	92	87.1	81	69	58.2	39.1	33	27.8	14.8	N/A	N/A	8.6	N/A	Passed	Passed	N/A	N/A
WR-19	96.2	93.3	88	79.9	72	53	44.4	32.9	30.1	28.5	18.1	N/A	N/A	7.5	N/A	Passed	Passed	N/A	N/A
WR-20	100	100	83		53		36	30		27	23	26	16	10	88	Failed	Passed	Passed	Passed

Table F5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Subbase Specifications			
	53	37.5	20	10	4.75	2.36	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
WR-21	100	100	84	53	37	31	27	22	33	18	15	68	Failed	Passed	Passed	Passed
WR-22	100	100	71	55	44	38	31	26	31	17	14	68	Failed	Passed	Passed	Passed
WR-23	100	100	89	66	45	38	34	28	30	21	9	68	Failed	Passed	Passed	Passed
WR-24	100	92	66	39	27	23	21	20	29	16	13	82	Failed	Passed	Passed	Passed
WR-25	100	100	88	74	36	24	21	18	35	20	15	80	Failed	Passed	Passed	Passed
WR-26	100	100	92	67	34	28	20	17	36	25	11	80	Failed	Passed	Failed	Passed
WR-27	100	100	85	63	42	35	31	27	34	22	12	82	Failed	Passed	Passed	Passed
WR-28	100	100	82	58	38	31	28	25	37	24	13	60	Failed	Passed	Failed	Passed
WR-29	100	100	87	68	51	45	40	33	28	14	14	56	Failed	Passed	Passed	Passed
WR-30	100	100	86	62	33	26	24	21	33	23	10	59	Failed	Passed	Passed	Passed
WR-31	100	100	89	73	43	34	32	30	41	29	12	52	Failed	Passed	Failed	Passed
WR-32	100	100	83	71	57	50	47	44	42	23	19	58	Failed	Failed	Failed	Passed
WR-33	100	100	72	43	29	24	21	18	29	16	13	79	Failed	Passed	Passed	Passed
WR-34	100	100	83	48	31	24	19	14	20	15	5	180	Failed	Passed	Passed	Passed
WR-35	100	100	83	62	44	37	32	28	31	18	13	72	Failed	Passed	Passed	Passed
WR-36	100	100	84	58	31	22	19	17	32	19	13	102	Failed	Passed	Passed	Passed
WR-37		100	100	87	45	30	25	21	35	20	15	45	Failed	Passed	Passed	Passed
WR-38		100	98	82	50	36	32	27	42	24	17	42	Failed	Failed	Failed	Passed
WR-39		100	94	75	52	42	38	30	39	25	14	40	Failed	Passed	Failed	Passed
WR-40		100	96	85	61	43	37	31	39	24	15	32	Failed	Passed	Failed	Passed

Table F5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test LL %	PL %	PI %	CBR at 98% %	Subbase Specifications Grading	PI≤ 16	LL≤ 35	CBR≥ 30
WR-41	100	99	90	57	45	37	30	38	25	13	22	Failed	Passed	Failed	Failed
WR-42	100	91	70	51	42	36	25	34	24	10	48	Failed	Passed	Passed	Passed
WR-43	97	96	86	48	37	32	24	34	23	11	54	Failed	Passed	Passed	Passed
WR-44	98	97	85	53	40	35	31	44	26	18	86	Failed	Failed	Failed	Passed
WR-45	100	93	75	49	40	37	35	58	35	24	64	Failed	Failed	Failed	Passed
WR-46	100	91	66	40	28	29	26	50	32	18	55	Failed	Passed	Failed	Passed
WR-47	100	94	72	45	38	34	26	40	25	15	59	Failed	Passed	Failed	Passed
WR-48	100	89	69	42	31	27	23	39	25	14	88	Failed	Passed	Failed	Passed
WR-49	100	92	67	45	34	27	25	43	28	16	95	Failed	Failed	Failed	Passed
WR-50					30	27	19	40	25	15	30	Failed	Passed	Failed	Passed
WR-51					34	27	16	28	19	9	48	Failed	Passed	Passed	Passed
WR-52					27	22	20	39	32	7	23	Failed	Passed	Failed	Failed
WR-53					34	26	14	34	21	14	36	Failed	Passed	Passed	Passed
WR-54					22	17	13	25	17	8	48	Failed	Passed	Passed	Passed
WR-55					20	14	11	38	22	15	36	Failed	Passed	Failed	Passed
WR-56					37	29	18	24	16	8	56	Failed	Passed	Passed	Passed
WR-57					26	22	18	21	14	7	51	Failed	Passed	Passed	Passed
WR-58					24	19	14	30	19	12	22	Failed	Passed	Passed	Failed
WR-59					45	38	32	45	23	22	14	Failed	Failed	Failed	Failed
WR-60					33	24	19	35	23	12	44	Failed	Passed	Passed	Passed

Table F5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Subbase Specifications

Sample Identification	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test LL %	PL %	PI %	CBR at 98% %	Subbase Specifications Grading	PI≤ 16	LL≤ 35	CBR≥ 30
WR-61					24	18	15	35	19	16	37	Passed	Passed	Passed	Passed
WR-62					32	16	12	30	20	10	40	Passed	Passed	Passed	Passed
WR-63					29	23	20	44	26	18	28	Passed	Failed	Failed	Failed
WR-64					38	32	28	44	30	14	16	Failed	Passed	Failed	Failed
WR-65					31	26	22	43	29	14	34	Passed	Passed	Failed	Passed
WR-66					26	18	11	23	18	5	53	Passed	Passed	Passed	Passed
WR-67					29	22	18	36	21	15	34	Passed	Passed	Failed	Passed
WR-68					44	38	28	39	23	16	17	Failed	Passed	Failed	Failed
WR-69					34	29	23	40	30	11	48	Failed	Passed	Failed	Passed
WR-70					33	26	16	23	13	10	59	Passed	Passed	Passed	Passed
WR-71					40	33	24	37	20	18	13	Failed	Failed	Failed	Failed
WR-72					22	16	12	32	19	13	31	Passed	Passed	Passed	Passed

Table F6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			CBR at 98%	Subbase Specifications			
	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR> 30
BAR-1	100	95	91.6	88	84	69.6	41.1	40.3	39.2	30	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
BAR-2	100	93	88.9	86	76	65.9	47.9	43.3	37.5	30	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-3	100	84	72.9	65	51	45	36.4	32.9	30.8	26.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-4	100	99	93.7	87	67	50.4	29.7	29.3	25.6	17	N/A	N/A	NP	N/A	Passed	Passed	N/A	N/A
BAR-5	100	97	93.9	85	63	45.4	21.5	17.3	16.3	10.2	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
BAR-6	100	100	100	98	90	74.7	37.2	28.2	24.9	12.6	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-7	100	95	80.3	72	58	48.2	41.3	38.2	36.2	18.3	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-8	100	74	58.6	54	47	43.7	39.4	37.8	33.4	14.6	N/A	N/A	NP	N/A	Passed	Passed	N/A	N/A
BAR-9	100	97	92.7	88	75	62	34.9	28.2	23.6	14.5	N/A	N/A	10.2	N/A	Passed	Passed	N/A	N/A
BAR-10	100	90	79.2	74	55	39	13	9.5	7.7	5.3	N/A	N/A	2.4	N/A	Failed	Passed	N/A	N/A
BAR-11	100	90	68	54	41	37.3	34.3	31.9	25.3	11	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-12	95.6	89	83.4	77	67	55.8	35.2	27.2	21	15.6	N/A	N/A	16.2	N/A	Failed	Failed	N/A	N/A
BAR-13	100	93	92.1	91	77	63.3	34.6	26.4	22.9	19.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-14	100	87	77	66	51	35.9	18.3	14.9	13.1	10.9	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-15	100	97	92	88	76	63.8	50.1	46.9	43	29.8	N/A	N/A	15	N/A	Failed	Passed	N/A	N/A
BAR-16	100	99	92	84	70	55.3	52	51.2	45.1	28.6	N/A	N/A	16	N/A	Failed	Passed	N/A	N/A
BAR-17							27		19	16	33	17	15	50	Passed	Passed	Passed	Passed
BAR-18							22		14	10	19	14	5	63	Passed	Passed	Passed	Passed
BAR-19							37		27	23	35	16	19	N/A	Failed	Failed	Passed	N/A
BAR-20							28		21	18	45	25	20	36	Failed	Failed	Failed	Passed

Table F6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Subbase specifications

Sample Identification	Gradation			Atterberg Limits			CBR at 98%	Subbase specification			
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. I %	P. I %		Grading	PI< 16	LL< 35	CBR> 30
BAR-21	75	11	14	18	14	4	44	N/A	Passed	Passed	Passed
BAP-22	88	12	0	23	18	5	83	N/A	Passed	Passed	Passed
BAR-23	70	19	11	15	12	3	46	N/A	Passed	Passed	Passed

Table F7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
ER-1	100		91.7	52	38	26.9	19.7	15.9	10.7	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-2	100		86.7	52	37	26.5	19.5	15.75	12.3	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-3	100		95.1	85	77	58	43.5	22.3	11	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-4	98		91.4	76	63	52.5	46.2	28.2	21.4	N/A	N/A	16.3	N/A	Passed	Failed	N/A	N/A
ER-5	97		86.1	76	66	53.5	47.5	31.4	25.9	N/A	N/A	13.3	N/A	Failed	Passed	N/A	N/A
ER-6	100		93	78	64	53.4	46.6	28.9	23.9	N/A	N/A	19.7	N/A	Failed	Failed	N/A	N/A
ER-7	98		88.8	72	58	48.7	42.5	25.2	19.4	N/A	N/A	19.6	N/A	Failed	Failed	N/A	N/A
ER-8	100		100	100	76	56.1	40.5	31.3	22.1	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-9	100		100	100	88	70	42	34	30	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-10	100		100	100	90	72	53	19	12	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-11			95	86	60	50	41	26	18	25	18	7	51	Passed	Passed	Passed	Passed
ER-12			98	94	86	69	39	18	9	21	15	6	134	Failed	Passed	Passed	Passed
ER-13			92	88	76	60	43	26	16	25	14	11	73	Failed	Passed	Passed	Passed
ER-14			95	83	67	45	27	17	10	23	17	6	99	Failed	Passed	Passed	Passed
ER-15			94	80	64	49	29	15	7	26	15	11	105	Failed	Passed	Passed	Passed
ER-16			95	85	72	57	42	23	9	23	11	12	67	Failed	Passed	Passed	Passed
ER-17	100	99		96	81	54	38	30	15	45	23	22	38	Passed	Failed	Failed	Passed
ER-18	100	100		100	87	57	38	30	15	47	23	24	N/A	Passed	Failed	Failed	N/A
ER-19	100	100		98	86	55	37	28	12	43	22	21	N/A	Passed	Failed	Failed	N/A
ER-20	100	95	86	68	45	37	31	25	13	28	16	12	40	Failed	Passed	Passed	Passed

Table F7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing										Atterberg Test			CBR at 98%	Subbase Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
ER-21	99	97	93	80	65	54	45	38	33	15	19	13	6	21	Passed	Passed	Passed	Failed
ER-22	98	94	88	72	61	50	42	38	31	16	25	15	10	45	Failed	Passed	Passed	Passed
ER-23	100	99	95	80	61	49	38	35	34	26	40	21	19	21	Failed	Failed	Failed	Failed
ER-24	100	99	96	81	61	46	35	29	22	14	37	21	16	35	Passed	Passed	Failed	Passed

Table F8: Grading and plastic limits of natural gravels in the Central Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Subbase Specifications			
	55 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR> 30
CR-1		100	92	85	78	62	49	26	19	16	13	43.5	26.8	16.7	N/A	Passed	Failed	Failed	N/A
CR-2		100	89	81	74	62	55	41	33	25	15	25.9	15.7	10.2	N/A	Passed	Passed	Passed	N/A
CR-3		100	88	83	77	61	49	31	25	22	18	42.8	29.8	13	N/A	Passed	Passed	Failed	N/A
CR-4		100	89	82	76	65	57	44	40	28	17	22.8	15.4	7.4	N/A	Passed	Passed	Passed	N/A
CR-5		100	77	64	54	42	36	28	24	21	17	33.5	20.2	13.3	N/A	Passed	Passed	Passed	N/A
CR-6		100	92	82	75	64	55	35	26	21	16	33.7	21.7	12	N/A	Passed	Passed	Passed	N/A
CR-7		100	87	82	76	66	60	41	30	20	13	24.7	15.9	8.8	N/A	Passed	Passed	Passed	N/A
CR-8		100	78	69	62	52	47	38	33	29	23	32.1	20	12.1	N/A	Failed	Passed	Passed	N/A
CR-9		100	85	76	68	57	49	35	28	21	14	31.5	18.7	12.8	N/A	Passed	Passed	Passed	N/A
CR-10		100	91	90	78	68	62	48	38	31	23	38.9	20	18.9	N/A	Failed	Failed	Failed	N/A
CR-11		100	94	90	87	78	71	49	38	28	20	30.7	18.4	12.3	N/A	Passed	Passed	Passed	N/A
CR-12		100	92	90	86	78	72	60	51	41	34	38.9	22	16.9	N/A	Failed	Failed	Failed	N/A
CR-13	100	100	90		61		31	24		17	13	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
CR-14	100	100	97		72		50	37		29	24	N/A	N/A	13	N/A	Failed	Passed	N/A	N/A
CR-15	100	95	74		48		33	25		18	14	N/A	N/A	14	N/A	Failed	Passed	N/A	N/A
CR-16	100	100	91		75		49	34		15	9	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
CR-17	100	100	87		78		53	38		16	7	N/A	N/A	4	N/A	Passed	Passed	N/A	N/A
CR-18	100	97	92		83		62	34		13	9	N/A	N/A	7	N/A	Passed	Passed	N/A	N/A
CR-19	100	100	96		87		67	44		21	15	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
CR-20	100	100	89		76		55	41		29.5	18	N/A	N/A	8.6	N/A	Passed	Passed	N/A	N/A

Table F8: Grading and plastic limits of natural gravels in the Central Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	75 mm	53 mm	37.5 mm	28 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR> 30
CR-21		100	98	81	64	50	36	18	17	N/A	N/A	14	N/A	Passed	Passed	N/A	N/A
CR-22		100	98	86	76	58	45	25	24	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
CR-23		100	100	100	93	79	40	17.5	11.5	N/A	N/A	11.8	N/A	Failed	Passed	N/A	N/A
CR-24		100	100	100	89	66	54	37.75	21.5	N/A	N/A	19.1	N/A	Failed	Failed	N/A	N/A
CR-25		100	100	100	81	58	39	22.9	17	N/A	N/A	12.9	N/A	Passed	Passed	N/A	N/A
CR-26		100	100	94	88	72	52	31.5	8.5	N/A	N/A	4.9	N/A	Passed	Passed	N/A	N/A
CR-27	100		95	91	84	69	43	21	11	23	12	11	106	Passed	Passed	Passed	Passed
CR-28	99		95	90	83	70	40	22	15	35	17	19	60	Passed	Failed	Passed	Passed
CR-29	100		96	91	81	69	43	22	15	29	14	15	90	Passed	Passed	Passed	Passed
CR-30	98		93	91	83	67	40	20	9	23	10	13	63	Passed	Passed	Passed	Passed
CR-31	99		96	94	86	65	35	20	10	25	11	14	67	Passed	Passed	Passed	Passed
CR-32	100		95	89	78	73	39	22	9	20	10	10	237	Passed	Passed	Passed	Passed
CR-33	100		99	97	90	76	42	21	12	27	12	15	99	Failed	Passed	Passed	Passed
CR-34	100		97	94	85	62	27	14	5	11	5	6	139	Passed	Passed	Passed	Passed
CR-35	100		98	95	83	62	38	19	9	17	9	8	101	Passed	Passed	Passed	Passed
CR-36	100		97	93	88	73	44	26	12	10	5	5	129	Passed	Passed	Passed	Passed
CR-37	99		95	86	76	57	32	20	10	34	13	21	72	Passed	Failed	Passed	Passed
CR-38	99		93	87	78	52	44	36	29	61	24	37	10	Failed	Failed	Failed	Failed
CR-39	100	100	97	91	85	70	40	12	7	28	14	14	42	Passed	Passed	Passed	Passed
CR-40	100		97	92	82	64	46	37	35	65	29	36	14	Failed	Failed	Failed	Failed

Table F8: Grading and plastic limits of natural gravels in the Central Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Subbase Specifications			
	75 mm	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
CR-41	100		93	89	82		67	47		24	20	28	12	16	113	Passed	Passed	Passed	Failed
CR-42	100	99	97	93	88		58	48	40	38	30	43	23	20	34	Failed	Failed	Failed	Passed
CR-43	100	100	96	85	70		57	38	34	30	21	35	17	18	36	Passed	Failed	Passed	Passed
CR-44	100	100	98	94	87		66	34	31	30	26	53	28	25	47	Failed	Failed	Failed	Passed
CR-45	100	100	98	92	64		46	45	36	34	25	42	21	19	15	Failed	Failed	Failed	Failed
CR-46	100	96	91	78	47		36	32	30	26	18	30	16	14	20	Passed	Passed	Passed	Failed
CR-47	100	100	92	84	56		38	26	23	22	20	62	27	35	26	Passed	Failed	Failed	Failed
CR-48	100	100	98	92	80		56	34	28	27	22	37	23	14	28	Passed	Passed	Failed	Failed
CR-49	100	100	96	85	62		46	39	37	33	26	44	21	23	38	Failed	Failed	Failed	Passed
CR-50	100	84	80	70	53		45	33	29	28	23	43	27	16	27	Failed	Passed	Failed	Failed
CR-51	100	100	96	86	66		46	31	23	20	15	42	23	19	20	Passed	Failed	Failed	Failed
CR-52	100	83	80	67	55		42	33	29	27	20	41	21	20	23	Failed	Failed	Failed	Failed
CR-53	100	99	96	88	63		40	21	13	8	1	36	19	16	74	Failed	Passed	Failed	Passed
CR-54	100	100	94	84	69		53	37	27	27	11	34	13	11	51	Passed	Passed	Passed	Passed
CR-55		100	98	96	69	59	50	33	24	16	5	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
CR-56		100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

Table F9: Grading and plastic limits of natural gravels in the Volta Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Subbase Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 16	LL≤ 35	CBR≥ 30
VR-1	100	98	85		58	44		25	14	N/A	N/A	8.8	N/A	Passed	Passed	N/A	N/A
VR-2	100	96	61		29	19		11	9	N/A	N/A	8.8	N/A	Failed	Passed	N/A	N/A
VR-3	100	92	74		52	41		26	14	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
VR-4	100	100	93		64	56		28	22	N/A	N/A	14.7	N/A	Failed	Passed	N/A	N/A
VR-5	100	100	65		44	25		17	10	N/A	N/A	5.1	N/A	Failed	Passed	N/A	N/A
VR-6	100	100	72		52	38		21	13	N/A	N/A	4.3	N/A	Failed	Passed	N/A	N/A
VR-7	100	100	93		74	79		52	13	N/A	N/A	4.3	N/A	Failed	Passed	N/A	N/A
VR-8	100	100	70		52.5	36		23	18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
VR-9	100	100	87		61	43		28	22	N/A	N/A	7.7	N/A	Passed	Passed	N/A	N/A
VR-10	100	96	84		60	51		29	16	N/A	N/A	6.2	N/A	Passed	Passed	N/A	N/A
VR-11	100	91	78		57	53		26	14	N/A	N/A	7.4	N/A	Passed	Passed	N/A	N/A
VR-12		99	98	63	29	24	22		14	39	22	17	50	Failed	Failed	Failed	Passed
VR-13			100	69	33	26	23		14	45	24	21	45	Passed	Failed	Failed	Passed
VR-14		100	95	71	38	20	17		8	40	25	15	55	Failed	Passed	Failed	Passed
VR-15			100	81	44	25	17		14	33	18	15	64	Passed	Passed	Passed	Passed
VR-16		100	98	86	47	24	20		12	28	17	11	60	Passed	Passed	Passed	Passed
VR-17		100	97	87	56	38	32		18	23	15	8	50	Passed	Passed	Passed	Passed
VR-18		100	98	86	57	1	33		14	21	14	7	70	Failed	Passed	Passed	Passed
VR-19		100	97	86	34	17	12		4	25	19	6	50	Failed	Passed	Passed	Passed
VR-20		100		71	16	16	12		6	28	18	10	57	Failed	Passed	Passed	Passed

Table F9: Grading and plastic limits of natural gravels in the Volta Region compared to Subbase Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 16	LL≤ 35	CBR≥ 30
VR-21	100		87	72	46	32	26		12	33	16	17	43	Passed	Failed	Passed	Passed
VR-22		100	99	77	48	32	27		18	46	26	20	45	Passed	Failed	Failed	Passed
VR-23			100	59	33	23	20		13	38	22	16	50	Passed	Failed	Failed	Passed
VR-24		99	98	65	29	21	17		12	39	21	18	40	Passed	Failed	Failed	Passed
VR-25			93			41		35	25	23	13	10	76	Failed	Passed	Passed	Passed
VR-26			100			43		27	7	21	20	1	168	Passed	Passed	Passed	Passed
VR-27			100			51		32	20	20	14	6	98	Passed	Passed	Passed	Passed
VR-28			100			43		34	23	23	17	6	66	Failed	Passed	Passed	Passed
VR-29			100			28		28	15	19	15	4	94	Passed	Passed	Passed	Passed
VR-30			99			33		26	21	20	14	6	96	Passed	Passed	Passed	Passed
VR-31			99			40		28	22	28	20	8	148	Passed	Passed	Passed	Passed
VR-32			99			36		25	20	27	20	7	98	Passed	Passed	Passed	Passed
VR-33			99			43		28	19	17	14	3	88	Passed	Passed	Passed	Passed
VR-34			99			37		33	24	19	13	6	60	Failed	Passed	Passed	Passed
VR-35			99			31		25	21	21	14	7	82	Passed	Passed	Passed	Passed
VR-36			99			27		22	16	20	4	16	81	Passed	Passed	Passed	Passed
VR-37			100			29		25	19	19	16	3	130	Passed	Passed	Passed	Passed
VR-38			100			49		31	21	19	16	3	55	Passed	Passed	Passed	Passed
VR-39			99			42		37	25	20	15	5	100	Failed	Passed	Passed	Passed

Table F10: Grading and plastic limits of natural gravels in the Greater Accra Region compared to Subbase specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Subbase Specifications: Grading	PI≤ 16	LL≤ 35	CBR≥ 30
GAR-1	100		98	79		59	41	33	27	18	22	12	10	80	Passed	Passed	Passed	Passed
GAR-2	100		100	91		62	39	31	25	14	20	14	6	N/A	Failed	Passed	Passed	N/A
GAR-3	100		100	81		57	37	32	28	16	19	12	7	N/A	Failed	Passed	Passed	N/A
GAR-4	100		93	70		54	46	43	38	22	18	11	7	50	Failed	Passed	Passed	Passed
GAR-5	100		99	97		81	52	41	33	20	29	16	13	22	Failed	Passed	Passed	Failed
GAR-6	100		100	96		68	41	33	26	16	23	12	11	N/A	Failed	Passed	Passed	N/A
GAR-7	100		100	91		72	39	28	21	14	24	13	11	N/A	Failed	Passed	Passed	N/A
GAR-8	100		100	95		77	48	37	31	19	24	11	13	N/A	Failed	Passed	Passed	N/A
GAR-9	100		98	83		58	43	39	33	17	22	9	13	50	Passed	Passed	Passed	Passed
GAR-10	100		100	89		70	37	27	19	11	20	10	10	N/A	Passed	Passed	Passed	N/A
GAR-11	99		91	77		58	36	29	22	14	28	15	13	50	Passed	Passed	Passed	Passed
GAR-12	100		98	92		73	48	33	26	17	22	12	10	N/A	Failed	Passed	Passed	N/A
GAR-13	100		95	87		68	42	30	24	15	24	13	11	N/A	Passed	Passed	Passed	N/A
GAR-14	100		96	89		59	38	32	24	15	19	11	8	N/A	Passed	Passed	Passed	N/A
GAR-15	100		97	87		67	38	28	21	12	24	14	10	70	Passed	Passed	Passed	Passed
GAR-16		96	85	67	53	46	34	24	15	8	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-17	100	98	92	68	51	44	34	30	25	15	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-18			100	96	83	74	52	42	33	19	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
GAR-19	100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-20	100	97	87	65	54	45	35	31	23	12	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-21		97	92	83		68	43		17	9	19	15	4	N/A	Passed	Passed	Passed	N/A

APPENDIX G:
COMPARING GRADING, CBR AND ATTERBERG LIMITS OF NATURAL GRAVELS WITH MOT G60 BASE REQUIREMENTS

KNUST

Table G1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI< 12	LL< 30	CBR> 60
NR-1	100	90	83	69	59	34	25	17	11	21.7	13.3	8.4	N/A	Passed	Passed	Passed	N/A
NR-2	100	93	87	68	49	23	15	13	11	24.3	15.7	8.6	N/A	Passed	Passed	Passed	N/A
NR-3	100	92	86	66	46	20	14	12	10	21.8	13.6	8.2	N/A	Failed	Passed	Passed	N/A
NR-4	100	91	82	63	51	30	23	20	17	22.6	15.1	7.5	N/A	Passed	Passed	Passed	N/A
NR-5	100	89	76	55	45	32	28	27	25	27.2	15.4	11.8	N/A	Passed	Passed	Passed	N/A
NR-6	100	98	91	77	65	44	34	29	23	26.3	15.4	10.9	N/A	Failed	Passed	Passed	N/A
NR-7	100	100	96	80	59	26	20	18	13	19.6	13.2	6.4	N/A	Failed	Passed	Passed	N/A
NR-8	100	97	90	77	64	33	21	17	14	33.5	20.7	12.8	N/A	Failed	Passed	Failed	N/A
NR-9	100		78		41.1	22.3	14.6	12.4	10.4	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
NR-10	100		95		58.5	33.8	23.9	20.2	16.8	N/A	N/A	11.1	N/A	Failed	Passed	N/A	N/A
NR-11	100		92		57.7	30.2	19.5	16.7	13	N/A	N/A	18.3	N/A	Failed	Failed	N/A	N/A
NR-12	100		90		63.7	46.8	42	38.8	25.6	N/A	N/A	17.3	N/A	Failed	Failed	N/A	N/A
NR-13	100		96		70.6	34.2	25.6	23.2	15.5	N/A	N/A	23.7	N/A	Failed	Failed	N/A	N/A
NR-14	100		87		53.6	27.2	17.7	13.9	9	N/A	N/A	13.3	N/A	Passed	Failed	N/A	N/A
NR-15	100		83		53.2	33	27.5	25.5	22.6	N/A	N/A	14.3	N/A	Failed	Failed	N/A	N/A
NR-16	100		99.5		88.4	40	24.2	21.5	14.4	N/A	N/A	12.3	N/A	Failed	Failed	N/A	N/A
NR-17	100		94		56.9	34.4	26.8	24	13.9	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
NR-18	100		97		70.9	33.6	24.8	23.4	19.4	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
NR-19	100		64		29.7	17.7	14	13	10.9	N/A	N/A	14.5	N/A	Failed	Failed	N/A	N/A
NR-20	100		99		93	53.2	47.2	38.1	33	N/A	N/A	16.2	N/A	Failed	Failed	N/A	N/A

Table G1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI< 12	LL< 30	CBR> 60
NR-21		100	100	85	47	24	18	16	12	N/A	N/A	16.4	N/A	Passed	Failed	N/A	N/A
NR-22		100	100	99	73	38	29	26	20	N/A	N/A	14	N/A	Failed	Failed	N/A	N/A
NR-23		100	100	97	73	39	30	28	19	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
NR-24		100	100	90	56	31	30	30	21	N/A	N/A	7.7	N/A	Passed	Passed	N/A	N/A
NR-25		100	100	97	57	33	27	26	19	N/A	N/A	3.9	N/A	Failed	Passed	N/A	N/A
NR-26		100	100	66	43	30	26	24	19	N/A	N/A	10.3	N/A	Passed	Failed	N/A	N/A
NR-27		100	100	94	56	31	25	24	17	N/A	N/A	14.3	N/A	Failed	Failed	N/A	N/A
NR-28	100	92	81	64	46	34		30	19	17.2	12.3	4.9	85	Passed	Passed	Passed	Passed
NR-29	100	91	78	53	36	31		29	14	17.8	12.3	5.5	75	Passed	Passed	Passed	Passed
NR-30		100	82	60	45	37		32	14	14.8	10.1	4.7	56	Passed	Passed	Passed	Failed
NR-31	100	98	84	63	42	30		26	13	17.8	10.6	7.2	80	Passed	Passed	Passed	Passed
NR-32	100	97	91	84	75	45		38	20	17.4	12.8	4.6	42	Failed	Passed	Passed	Failed
NR-33	100	95	92	79	50	32		20	6	17.4	12.7	4.7	45	Passed	Passed	Passed	Failed
NR-34	100	95	91	80	48	25		18	7	18.2	12.5	5.7	55	Passed	Passed	Passed	Failed
NR-35	100	96	90	78	60	40		32	23	17	13.5	3.5	32	Passed	Passed	Passed	Failed
NR-36		100	95	81	50	29		25	12	NP	NP	NP	35	Passed	Passed	Passed	Failed
NR-37	100	96	79	68	46	27		19	7	26.6	18	8.6	55	Passed	Passed	Passed	Failed
NR-38		100	91	84	64	45		36	14	21.2	14.7	6.5	50	Failed	Passed	Passed	Failed
NR-39	100	89	78	54	38	25		20	15	24.6	18.8	5.8	51	Passed	Passed	Passed	Failed
NR-40	100	96	89	68	40	25		11	5	22.2	17.2	5	65	Passed	Passed	Passed	Passed

Table G1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 12	LL≤ 30	CBR≥ 60
NR-41	100	97	92	86	57	33		25	19	21.8	14.9	6.9	23	Passed	Passed	Passed	Failed
NR-42	100	95	83	72	54	29		21	17	23.8	18.2	5.6	20	Passed	Passed	Passed	Failed
NR-43	100	95	89	75	60	43		29	13	19.8	13.8	6	33	Passed	Passed	Passed	Failed
NR-44		100	93	90	75	48		34	11	19.4	13.9	5.5	46	Passed	Passed	Passed	Failed
NR-45	100	97	92	80	59	37		22	9	17.8	13.4	4.4	60	Passed	Passed	Passed	Passed
NR-46		100	85	65	42	31	23	17	7	19	14	5	95	Passed	Passed	Passed	Passed
NR-47		100	90	70	41	24	20	18	14	18	13	5	69	Passed	Passed	Passed	Passed
NR-48		100	95	75	66	43	41	39	32	57	25	31	50	Failed	Failed	Failed	Failed
NR-49		100	91	70	40	20	14	15	10	19	13	6	90	Failed	Passed	Passed	Passed
NR-50		100	89	74	49	29	25	21	11	NP	NP	NP	50	Passed	Passed	Passed	Failed
NR-51		100	94	70	31	16	13	9	3	NP	NP	NP	50	Failed	Passed	Passed	Failed
NR-52		100	98	79	49	24	23	14	9	NP	NP	NP	118	Passed	Passed	Passed	Passed
NR-53		100	99	84	41	22	18	12	5	NP	NP	NP	125	Passed	Passed	Passed	Passed
NR-54		100	100	90	56	36	29	20	11	NP	NP	NP	N/A	Passed	Passed	Passed	N/A
NR-55		100	100	89	57	33	27	19	7	NP	NP	NP	N/A	Passed	Passed	Passed	N/A
NR-56		100	100	88	45	24	20	14	7	NP	NP	NP	200	Passed	Passed	Passed	Passed
NR-57		100	94	69	37	33	28	16	5	NP	NP	NP	32	Passed	Passed	Passed	Failed
NR-58		100	90	76	52	36	28	15	8	NP	NP	NP	44	Passed	Passed	Passed	Failed
NR-59		100	83	59	43	27	21	19	13	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-60		100	85	67	42	29	23	17	7	NP	NP	NP	102	Passed	Passed	Passed	Passed

Table G1: Grading, CBR and Atterberg's limits of natural gravels in the Northern Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 12	LL≤ 30	CBR≥ 60
NR-61	100	83	62	48	40	29	21	11	NP	NP	NP	93	Passed	Passed	Passed	Passed
NR-62	100	88	68	41	27	22	18	11	NP	NP	NP	60	Passed	Passed	Passed	Passed
NR-63	100	89	55	33	25	22	18	11	NP	NP	NP	97	Passed	Passed	Passed	Passed

Sample Identification	Gradation: Gravel %	Sand %	Silt+Clay %	Atterberg limits: L.L. %	P.L %	P.I %	CBR at 98%	Base specification: Grading	PI<12	LL<30	CBR>60
NR-64	57	15	28	20	14	6	70	N/A	Passed	Passed	Passed
NR-65	81	7	12	20	15	5	49	N/A	Passed	Passed	Failed
NR-66	80	5	15	21	14	7	66	N/A	Passed	Passed	Passed
NR-67	76	5	19	29	19	10	27	N/A	Passed	Passed	Failed
NR-68	77	9	14	16	13	3	73	N/A	Passed	Passed	Passed

Table G2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Base specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
UWR-1		100	94	86	61	38	33		16	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 2		100	94	63	35	22	17		15	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 3		100	100	87	47	34	29		18	N/A	N/A	14	N/A	Passed	Failed	N/A	N/A
UWR- 4		100	89	69	41	27	22		10	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR- 5		100	87	61	37	30	23		11	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR- 6		100	98	88	60	39	32		12	N/A	N/A	9.1	N/A	Passed	Passed	N/A	N/A
UWR- 7		92	94	80	55	41	33		19	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
UWR- 8		100	97	90	69	41	36		13	N/A	N/A	7	N/A	Passed	Passed	N/A	N/A
UWR- 9		100	95	82	58	41	33		13	N/A	N/A	6	N/A	Passed	Passed	N/A	N/A
UWR -10		100	96	87	63	44	30		19	N/A	N/A	10	N/A	Passed	Passed	N/A	N/A
UWR -11		96	95	76	47	33	26		10	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR -12		100	100	81	52	36	34		8	N/A	N/A	6	N/A	Passed	Passed	N/A	N/A
UWR -13		81	78	57	40	31	29		9	N/A	N/A	4	N/A	Passed	Passed	N/A	N/A
UWR -14		100	96	87	56	36	29		13	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
UWR -15		100	95	86	61	34	31		12	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
UWR -16		100	100	91	70	54	42		19	N/A	N/A	5.7	N/A	Failed	Passed	N/A	N/A
UWR -17	100	90	82	77	55	36		20	8	20.6	13.1	7.5	45	Failed	Passed	Passed	Failed
UWR -18	100	99	97	90	65	35		22	13	34.6	20.5	14.1	73	Passed	Failed	Failed	Passed
UWR -19		100	99	94	70	48		28	13	21.2	17	4.2	47	Passed	Passed	Passed	Failed
UWR -20	100	83	86	76	50	29		20	8	23	18.5	4.5	60	Passed	Passed	Passed	Passed

Table G2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Base specifications

Sample Identification	Grading: Percentage Passing								Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
UWR -21	100	86	65	48	31	21	14	7	26.5	17.1	9.4	50	Passed	Passed	Passed	Failed
UWR -22			100	87	55	43	23	13	18.8	14.1	4.7	56	Passed	Passed	Passed	Failed
UWR -23		100	99	97	80	49	23	8	21	14.5	6.5	80	Passed	Passed	Passed	Passed
UWR -24		100	95	89	63	37	21	10	21.8	16.6	5.2	40	Passed	Passed	Passed	Failed
UWR -25	100	100	95	82	63	38	31	19	26.1	16.9	9.2	38	Passed	Passed	Passed	Failed
UWR -26	100	99	90	79	62	45	26	12	20	14.1	5.9	45	Passed	Passed	Passed	Failed
UWR -27	100	98	86	61	40	23	15	6	17.6	12.7	4.9	60	Passed	Passed	Passed	Passed
UWR -28	100	95	82	69	49	30	21	7	19.1	14.1	5	60	Passed	Passed	Passed	Passed
UWR -29			100	94	70	41	26	13	26.2	14.3	11.9	45	Passed	Failed	Passed	Failed
UWR -30		100	98	82	51	32	26	13	27.3	15.3	12	55	Passed	Failed	Passed	Failed
UWR -31		100	100	97	82	61	36	19	24.7	15.7	9	45	Passed	Passed	Passed	Failed
UWR -32		100	98	89	65	43	29	11	23.1	17.2	5.9	70	Passed	Passed	Passed	Passed
UWR -33		100	98	85	53	37	28	13	20.5	12.6	7.9	60	Failed	Passed	Passed	Passed
UWR -34	100	99	94	71	44	33	23	11	20.9	15.3	5.6	70	Failed	Passed	Passed	Passed
UWR -35		100	99	95	79	43	29	13	17.6	11.9	5.7	78	Failed	Passed	Passed	Passed
UWR -36	100	99	83	72	53	39	29	15	22.4	15.2	7.2	47	Passed	Passed	Passed	Passed
UWR -37	100	99	91	72	57	40	31	19	28.7	16.9	11.8	45	Passed	Failed	Passed	Failed
UWR -38		100	99	82	67	43	37	26	21.5	16.5	5	55	Failed	Passed	Passed	Failed
UWR -39		100	93	83	62	42	30	22	23.6	18.5	5.1	55	Failed	Passed	Passed	Failed
UWR -40			88			46	24	13	NP	NP	NP	100	Passed	Passed	Passed	Passed

Table G2: Grading, CBR and Atterberg's Limits of natural gravels in the Upper West Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI< 12	LL< 30	CBR> 60
UWR -41					52	33	17	24	19	5	30	Passed	Passed	Passed	Failed
UWR -42					35	25	16	23	19	4	95	Passed	Passed	Passed	Passed
UWR -43		98			34	17	13	26	25	1	42	Passed	Passed	Passed	Failed
UWR -44		97			39	25	18	24	19	4	23	Passed	Passed	Passed	Failed
UWR -45		100			48	27	17	24	20	4	50	Passed	Passed	Passed	Failed
UWR -46		83			21	15	14	32	22	10	73	Passed	Passed	Failed	Passed
UWR -47					40	23	18	32	16	16	18	Failed	Failed	Failed	Failed
UWR -48		100			39	23	11	32	16	16	67	Passed	Failed	Failed	Passed
UWR -49		78			42	32	16	21	15	6	48	Passed	Passed	Passed	Failed
UWR -50		96			46	29	15	34	19	15	67	Passed	Failed	Failed	Passed
UWR -51		82			39	26	15	26	17	9	42	Failed	Passed	Passed	Failed
UWR -52		89			21	15	13	29	19	10	70	Passed	Passed	Passed	Passed
UWR -53		94			39	26	8	23	19	4	50	Passed	Passed	Passed	Failed
UWR -54		95			42	32	29	18	16	2	28	Failed	Passed	Passed	Failed
UWR -55		100			68	45	36	27	19	8	37	Failed	Passed	Passed	Failed
UWR -56		99			56	35	18	20	19	1	53	Passed	Passed	Passed	Failed
UWR -57		83			21	16	6	NP	NP	NP	128	Passed	Passed	Passed	Passed

Table G3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	13.2 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI< 12	LL< 30	CBR> 60
UER-1	100	100	99	94	91	76	57		15	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-2	100	100	92	81	75	66	57		20	N/A	N/A	17	N/A	Failed	Failed	N/A	N/A
UER-3	100	100	96	95	94	85	72		19	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-4	93	93	90	88	84	75	66		22	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
UER-5	100	100	99	90	81	72	60		18	N/A	N/A	18	N/A	Failed	Failed	N/A	N/A
UER-6	100	100	96	95	94	82	58		21	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-7	100	100	97	89	81	70	61		16	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
UER-8	100	100	95	91	88	72	63		16	N/A	N/A	10	N/A	Failed	Passed	N/A	N/A
UER-9	100	100	93	91	85	73	52		18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
UER-10	100	100	94	90	88	80	75		19	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
UER-11			79				24	13	7	NP	NP	NP	120	Passed	Passed	Passed	Passed
UER-12			93				40	22	14	22	15	7	50	Failed	Passed	Passed	Passed
UER-13		100				68	36	23		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-14		100				70	52	34		N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
UER-15		100				57	32	19		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-16		100				63	36	21		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
UER-17		100				44	27	15		N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

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Table G3: Grading, CBR and Atterberg's Limits of natural gravels in the Upper East Region compared to Base specifications

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Base specification			
	Gravel %	Sand %	Silt+Clay %	L.L. %	P.I. %	P.L %		Grading	PI< 10	LL< 30	CBR> 60
UER-18	75	9	16	21	14	7	21	N/A	Passed	Passed	Failed
UER-19	61	21	18	21	14	7	33	N/A	Passed	Passed	Failed

Table G4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Base specifications

Sample Identification	Grading											Atterberg Test			CBR at 98%	Base Specifications			
	Percentage Passing																		
	53 mm	37.5 mm	26 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
AR-1	100	100	89	58	45	38	33	24	23	22	22	44	21	23	N/A	Passed	Failed	Failed	N/A
AR-2	100	100	82	59	49	43	33	27	21	19	18	35	19	15	N/A	Passed	Failed	Failed	N/A
AR-3	100	100	75	57	52	47	41	32	28	21	19	36	17	19	N/A	Passed	Failed	Failed	N/A
AR-4	100	100	78	59	47	37	31	21	17	15	14	33	17	16	N/A	Passed	Failed	Failed	N/A
AR-5	100	100	99	94	81	72	57	32	24	21	18	31	16	15	N/A	Passed	Failed	Failed	N/A
AR-6	100	100	98	91	80	65	54	37	33	28	15	37	20	17	N/A	Passed	Failed	Failed	N/A
AR-7	100	100	92	87	81	69	57	39	33	31	26	40	22	19	N/A	Failed	Failed	Failed	N/A
AR-8	-	-	-	-	-	-	-	-	-	-	-	44	20	24	N/A	N/A	Failed	Failed	N/A
AR-9	100	92	77	66	55	38	29	21	19	18	16	52	25	24	N/A	Failed	Failed	Failed	N/A
AR-10	100	100	100	98	89	64	48	28	24	21	15	52	25	26	N/A	Passed	Failed	Failed	N/A
AR-11	100	100	99	94	89	75	62	41	35	31	25	49	26	23	N/A	Failed	Failed	Failed	N/A
AR-12	100	100	100	72	60	48	36	24	20	14	11	24	14	9	N/A	Failed	Passed	Passed	N/A
AR-13	100	100	91	85	75	54	42	23	18	13	10	43	26	17	N/A	Passed	Failed	Failed	N/A
AR-14	100	100	97	90	84	73	61	38	33	30	28	53	25	28	N/A	Passed	Failed	Failed	N/A
AR-15	93	85	75	55	42	34	30	23	21	18	14	38	20	18	N/A	Failed	Failed	Failed	N/A
AR-16	100	97	93	86	79	74	70	57	42	29	23	46	22	24	N/A	Passed	Failed	Failed	N/A
AR-17	100	95	83	76	68	60	52	38	31	28	24	42	21	21	N/A	Failed	Failed	Failed	N/A
AR-18			92					35		24	21	28	17	11	38	Passed	Passed	Passed	Failed
AR-19			90					24		18	12	22	17	5	38	Passed	Passed	Passed	Failed
AR-20			92					18		12	9	25	18	7	98	Failed	Passed	Passed	Passed

Table G4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region with compared to Base specifications

Sample Identification	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test LL %	PL %	PI %	CBR at 98% %	Base Specifications Grading	PI≤ 12	LL≤ 30	CBR≥ 60
AR-21		89			22	17	14	34	15	19	76	Failed	Failed	Failed	Passed
AR-22		92			45	21	18	36	22	12	35	Passed	Passed	Failed	Failed
AR-23		91			24	15	10	25	17	8	78	Passed	Passed	Passed	Passed
AR-24		94			50	28	16	24	16	8	56	Passed	Passed	Passed	Failed
AR-25		96			35	20	13	32	24	8	99	Passed	Failed	Failed	Passed
AR-26		98			36	20	10	27	15	12	60	Passed	Passed	Passed	Passed
AR-27		94			15	11	8	23	17	6	94	Failed	Passed	Passed	Passed
AR-28		91			12	7	5	23	16	7	138	Failed	Passed	Passed	Passed
AR-29		92			26	22	19	32	25	7	18	Passed	Passed	Failed	Failed
AR-30		93			37	27	23	49	20	29	40	Passed	Failed	Failed	Failed
AR-31		87			45	17	9	36	19	17	40	Failed	Failed	Failed	Failed
AR-32		89			36	25	19	39	22	16	50	Passed	Failed	Failed	Failed
AR-33		94			39	31	25	33	20	12	35	Passed	Passed	Failed	Failed
AR-34		70			26	19	14	42	19	23	35	Failed	Failed	Failed	Failed
AR-35		87			34	25	19	17	9	8	90	Failed	Passed	Passed	Passed
AR-36		95			42	25	16	28	16	12	100	Passed	Passed	Passed	Passed
AR-37		85			18	13	9	19	10	9	89	Passed	Passed	Passed	Passed
AR-38		84			22	16	11	18	9	9	64	Failed	Passed	Passed	Passed
AR-39		86			20	14	10	23	15	8	95	Failed	Passed	Passed	Passed
AR-40		72			30	23	20	43	23	20	35	Failed	Failed	Failed	Failed

Table G4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Base specifications

Sample Identification	75 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test LL %	PL %	PI %	CBR at 98% %	Base Specifications Grading	PI≤ 12	LL≤ 30	CBR≥ 60
AR-41		69			30	25	21	37	21	16	40	Failed	Failed	Failed	Failed
AR-42		90			34	19	14	27	16	11	60	Failed	Passed	Passed	Passed
AR-43		71			31	24	21	36	19	17	47	Passed	Failed	Failed	Failed
AR-44		88			43	16	11	29	16	13	60	Failed	Failed	Passed	Passed
AR-45		89			27	15	13	20	11	9	65	Passed	Passed	Passed	Passed
AR-46		90			29	21	14	27	10	17	45	Passed	Failed	Passed	Failed
AR-47		90			38	25	19	23	12	11	80	Passed	Passed	Passed	Passed
AR-48		90			37	27	19	30	16	14	80	Passed	Failed	Passed	Passed
AR-49		90			34	22	14	23	11	12	87	Passed	Passed	Passed	Passed
AR-50		84			19	14	9	17	9	8	82	Passed	Passed	Passed	Passed
AR-51		90			36	29	21	39	23	16	40	Passed	Failed	Failed	Failed
AR-52		84			20	14	10	24	14	10	95	Passed	Passed	Passed	Passed
AR-53		86			20	15	11	24	14	10	100	Failed	Passed	Passed	Passed
AR-54		86			31	24	10	31	19	12	60	Failed	Passed	Failed	Passed
AR-55		96			26	21	16	39	20	19	60	Passed	Failed	Failed	Passed
AR-56		94			22	14	9	23	11	12	100	Passed	Passed	Passed	Passed
AR-57		87			25	17	11	21	10	11	82	Failed	Passed	Passed	Passed
AR-58		98			37	26	18	28	16	12	47	Passed	Passed	Passed	Failed
AR-59		84			19	14	9	19	10	9	78	Passed	Passed	Passed	Passed
AR-60		86			18	13	10	22	12	10	93	Failed	Passed	Passed	Passed

Table G4: Grading, CBR and Atterberg's Limits of natural gravels in the Ashanti Region compared to Base specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	75	53	37.5	20	10	4.75	2.36	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
AR-61				88			26	18	14	34	17	17	98	Failed	Failed	Failed	Passed
AR-62				91			26	17	9	23	11	12	52	Passed	Passed	Passed	Failed
AR-63				88			22	22	14	24	12	12	100	Passed	Passed	Passed	Passed
AR-64	100		100	100	95	75	56	40	27	38	18	20	75	Passed	Failed	Failed	Passed
AR-65	100		100	92	86	70	49	29	18	28	17	11	57	Failed	Failed	Passed	Failed
AR-66	100		100	91	81	61	46	29	17	30	18	12	50	Passed	Passed	Passed	Failed
AR-67				100			43	31	26	46	12	34	35	Passed	Passed	Failed	Failed

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Base specification			
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. L. %	P. I. %		Grading	PI< 12	LL< 30	CBR> 60
AR-68	81	10	9	N/A	N/A	N/A	59	N/A	N/A	N/A	Failed
AR-69	88	6	6	N/A	N/A	N/A	100	N/A	N/A	N/A	Passed
AR-70	52	16	32	N/A	N/A	N/A	42	N/A	N/A	N/A	Failed
AR-71	65	19	6	N/A	N/A	N/A	66	N/A	N/A	N/A	Passed
AR-72	56	24	20	N/A	N/A	N/A	95	N/A	N/A	N/A	Passed
AR-73	82	10	8	N/A	N/A	N/A	23	N/A	N/A	N/A	Failed
AR-74	59	20	21	N/A	N/A	N/A	96	N/A	N/A	N/A	Passed
AR-75	68	15	17	N/A	N/A	N/A	53	N/A	N/A	N/A	Failed

Table G5: Grading, CBR and Atterberg's Limits of natural gravels in the Western compared to Base Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Base Specifications			
	53	37.5	20	13.2	10	6.7	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
WR-1	100	94.6	85	76.9	69	53	46.8	32.6	29.8	25.9	20.3	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
WR-2	100	100	79	63	47	38	29.7	25.9	23.1	20.4	16.3	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
WR-3	100	100	88	80.3	73	64	54.1	33.2	30.4	27.6	18.9	N/A	N/A	12	N/A	Passed	Passed	N/A	N/A
WR-4	93	90	79	73	62	55	48	41	38	25	13	N/A	N/A	4.5	N/A	Passed	Passed	N/A	N/A
WR-5	100	95	88	85	80	74	68	54	47	31	19	N/A	N/A	12.2	N/A	Failed	Failed	N/A	N/A
WR-6	97	95	81	73	67	59	51	39	33	24	17	N/A	N/A	12.4	N/A	Passed	Failed	N/A	N/A
WR-7	100	100	85	80.9	77	64	51.4	29.8	27.3	24.7	19.6	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
WR-8	100	100	86	77.3	69	62	55.8	46.9	39.5	32	20.2	N/A	N/A	14.8	N/A	Passed	Failed	N/A	N/A
WR-9	100	100	95	89.9	85	74	62.8	44	41.5	38.9	36.1	N/A	N/A	22	N/A	Failed	Failed	N/A	N/A
WR-10	100	100	95	88.8	82	62	49	33.6	29	27.4	21	N/A	N/A	8.4	N/A	Passed	Passed	N/A	N/A
WR-11	98.8	96.3	90	86.2	82	75	67.4	36.4	28.2	18.6	12.7	N/A	N/A	2.8	N/A	Passed	Passed	N/A	N/A
WR-12	100	72.8	61	52.7	44	30	25.1	20.4	15.8	12.8	7.9	N/A	N/A	13	N/A	Failed	Failed	N/A	N/A
WR-13	100	98.3	84	65.8	54	41	38	27.1	24.2	19.9	16	N/A	N/A	18.5	N/A	Passed	Failed	N/A	N/A
WR14	100	100	91	85	78	65	59.8	44.8	36.5	25.5	17.7	N/A	N/A	9.9	N/A	Passed	Passed	N/A	N/A
WR-15	97	91	83	77.4	67	53	47	31.6	28.4	21.7	16.7	N/A	N/A	8.5	N/A	Passed	Passed	N/A	N/A
WR-16	69.4	61.6	51	47	42	33	25.5	20	16.5	13.6	11	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
WR-17	100	97.5	96	90.4	83	68	55.5	37.3	31.2	28.7	22	N/A	N/A	13.5	N/A	Passed	Failed	N/A	N/A
WR-18	96.3	94.7	92	87.1	81	69	58.2	39.1	33	27.8	14.8	N/A	N/A	8.6	N/A	Passed	Passed	N/A	N/A
WR-19	96.2	95.3	88	79.9	72	53	44.4	32.9	30.1	28.5	18.1	N/A	N/A	7.5	N/A	Passed	Passed	N/A	N/A
WR-20	100	100	83		53		36	30		27	23	26	16	10	88	Failed	Passed	Passed	Passed

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Table G5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 12	LL< 30	CBR≥ 60
WR-21	100	100	84	53	37	31	27	22	33	18	15	68	Failed	Failed	Failed	Passed
WR-22	100	100	71	55	44	38	31	26	31	17	14	68	Failed	Failed	Failed	Passed
WR-23	100	100	89	66	45	38	34	28	30	21	9	68	Failed	Passed	Passed	Passed
WR-24	100	93	66	39	27	23	21	20	29	16	13	82	Failed	Failed	Passed	Passed
WR-25	100	100	88	74	36	24	21	18	35	20	15	80	Failed	Failed	Failed	Passed
WR-26	100	100	92	69	34	28	20	17	36	25	11	80	Failed	Passed	Failed	Passed
WR-27	100	100	85	63	42	35	31	27	34	22	12	82	Failed	Passed	Failed	Passed
WR-28	100	100	82	58	38	31	28	25	37	24	13	80	Failed	Failed	Failed	Passed
WR-29	100	100	87	68	53	45	40	36	28	14	14	56	Failed	Failed	Passed	Failed
WR-30	100	100	86	62	33	26	24	21	33	23	10	99	Failed	Passed	Failed	Failed
WR-31	100	100	89	73	43	34	32	30	41	29	12	52	Failed	Passed	Failed	Failed
WR-32	100	100	83	71	57	50	47	44	42	23	19	58	Failed	Failed	Failed	Failed
WR-33	100	100	72	43	29	24	21	18	29	16	13	79	Failed	Failed	Passed	Passed
WR-34	100	100	83	48	31	24	19	14	20	15	5	180	Failed	Passed	Passed	Passed
WR-35	100	100	83	62	44	37	32	28	31	18	13	72	Failed	Failed	Failed	Passed
WR-36	100	100	84	58	31	22	19	17	32	19	13	102	Failed	Failed	Failed	Passed
WR-37		100	100	87	65	30	25	21	35	20	15	45	Failed	Failed	Failed	Failed
WR-38		100	98	82	50	36	32	27	42	24	17	42	Failed	Failed	Failed	Failed
WR-39		100	94	75	52	42	38	30	39	25	14	40	Failed	Failed	Failed	Failed
WR-40		100	96	85	61	43	37	31	39	24	15	32	Failed	Failed	Failed	Failed

Table D5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 12	LL< 30	CBR> 60
WR-41	100	99	90	57	45	37	30	38	25	13	22	Failed	Failed	Failed	Failed
WR-42	100	91	70	51	42	36	25	34	24	10	48	Failed	Passed	Failed	Failed
WR-43	97	96	86	48	37	32	24	34	23	11	54	Failed	Passed	Failed	Failed
WR-44	98	97	85	53	40	35	31	44	26	18	86	Failed	Failed	Failed	Passed
WR-45	100	93	75	49	40	37	35	58	35	24	64	Failed	Failed	Failed	Passed
WR-46	100	91	66	40	28	29	26	50	32	18	55	Failed	Failed	Failed	Failed
WR-47	100	94	72	45	38	34	26	40	25	15	59	Failed	Failed	Failed	Failed
WR-48	100	89	69	42	31	27	23	39	25	14	88	Failed	Failed	Failed	Passed
WR-49	100	92	67	45	34	27	25	43	28	16	95	Failed	Failed	Failed	Passed
WR-50					30	27	19	40	25	15	30	Failed	Failed	Failed	Failed
WR-51					34	27	16	28	19	9	48	Failed	Passed	Passed	Failed
WR-52					27	22	20	39	32	7	23	Failed	Passed	Failed	Failed
WR-53					34	26	14	34	21	14	36	Failed	Failed	Failed	Failed
WR-54					22	17	13	25	17	8	48	Passed	Passed	Passed	Failed
WR-55					20	14	11	38	22	15	36	Passed	Failed	Failed	Failed
WR-56					37	29	18	24	16	8	56	Failed	Passed	Passed	Failed
WR-57					26	23	18	21	14	7	31	Failed	Passed	Passed	Failed
WR-58					24	19	14	30	19	12	22	Passed	Passed	Passed	Failed
WR-59					45	38	32	45	23	22	14	Failed	Failed	Failed	Failed
WR-60					33	24	19	35	23	12	44	Failed	Failed	Failed	Failed

Table G5: Grading, CBR and Atterberg's Limits of natural gravels in the Western Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98% %	Base Specifications: Grading	PI≤ 12	LL≤ 30	CBR≥ 60
WR-61					24	18	15	35	19	16	37	Passed	Failed	Failed	Failed
WR-62					32	16	12	30	20	10	40	Passed	Passed	Passed	Failed
WR-63					29	23	20	44	26	18	28	Passed	Failed	Failed	Failed
WR-64					38	32	28	44	30	14	16	Failed	Failed	Failed	Failed
WR-65					31	26	22	43	29	14	34	Passed	Failed	Failed	Failed
WR-66					26	18	11	23	18	5	53	Passed	Passed	Passed	Failed
WR-67					29	22	18	36	21	13	34	Passed	Failed	Failed	Failed
WR-68					44	38	28	39	23	16	17	Failed	Failed	Failed	Failed
WR-69					34	29	23	40	30	11	48	Failed	Passed	Failed	Failed
WR-70					33	26	16	23	13	10	59	Passed	Passed	Passed	Failed
WR-71					40	33	24	37	20	18	13	Failed	Failed	Failed	Failed
WR-72					22	16	12	32	19	13	31	Passed	Failed	Failed	Failed

Table G6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Base specifications

Sample Identification	Grading: Percentage Passing 37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 95% %	Base Specifications: Grading	PI≤ 12	LL≤ 30	CBR≥ 60
BAR-1	100	95	91.6	88	84	69.6	41.1	40.3	39.2	30	N/A	N/A	12	N/A	Failed	Passed	N/A	N/A
BAR-2	100	93	88.9	86	76	65.9	47.9	41.3	37.5	30	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-3	100	84	72.9	65	51	45	36.4	32.9	30.8	25.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-4	100	99	93.7	87	67	50.4	29.7	29.3	25.6	17	N/A	N/A	NP	N/A	Passed	Passed	N/A	N/A
BAR-5	100	97	93.9	85	63	45.4	21.5	17.3	16.3	13.2	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
BAR-6	100	100	100	98	90	74.7	37.2	28.2	24.9	12.6	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-7	100	95	80.3	72	58	48.2	41.3	34.2	36.2	18.3	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-8	100	74	58.6	54	47	43.7	39.4	37.8	33.4	14.6	N/A	N/A	NP	N/A	Passed	Passed	N/A	N/A
BAR-9	100	97	92.7	88	75	62	34.9	28.2	23.6	14.5	N/A	N/A	10.2	N/A	Passed	Passed	N/A	N/A
BAR-10	100	90	79.2	74	55	39	13	9.5	7.7	5.3	N/A	N/A	2.4	N/A	Failed	Passed	N/A	N/A
BAR-11	100	90	68	54	41	37.3	34.3	31.9	25.3	11	N/A	N/A	NP	N/A	Failed	Passed	N/A	N/A
BAR-12	95.6	89	83.4	77	67	55.8	35.2	27.2	21	15.6	N/A	N/A	16.2	N/A	Failed	Failed	N/A	N/A
BAR-13	100	93	92.1	91	77	63.3	34.6	26.4	22.9	19.8	N/A	N/A	19	N/A	Failed	Failed	N/A	N/A
BAR-14	100	87	77	66	51	35.9	18.3	14.9	13.1	10.9	N/A	N/A	11	N/A	Failed	Passed	N/A	N/A
BAR-15	100	97	92	88	76	63.8	50.1	46.9	43	29.8	N/A	N/A	15	N/A	Failed	Failed	N/A	N/A
BAR-16	100	99	92	84	70	55.3	52	51.2	45.1	28.6	N/A	N/A	16	N/A	Failed	Failed	N/A	N/A
BAR-17							27		19	16	33	17	15	60	Passed	Failed	Failed	Passed
BAR-18							22		14	10	19	14	5	63	Passed	Passed	Passed	Passed
BAR-19							37		27	23	35	16	19		Failed	Failed	Failed	
BAR-20							28		21	18	45	25	20	36	Failed	Failed	Failed	Failed

Table C6: Grading, CBR and Atterberg's Limits of natural gravels in the Brong Ahafo Region compared to Base specifications

Sample Identification	Gradation			Atterberg limits			CBR at 98%	Base specification			
	Gravel %	Sand %	Silt+Clay %	L. L. %	P. I. %	P. I. %		Grading	PI< 12	LL< 30	CBR> 60
BAR-21	75	11	14	18	14	4	44	N/A	Passed	Passed	Failed
BAR-22	88	12	0	23	18	5	83	N/A	Passed	Passed	Passed
BAR-23	70	19	11	15	12	3	46	N/A	Passed	Passed	Failed

Table C7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region with compared to Base Specifications

Sample Identification	Grading									Atterberg Test			CBR at 98%	Base Specifications			
	Percentage Passing																
	75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
ER-1	100		91.7	50	38	26.9	19.7	15.9	10.7	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-2	100		86.7	50	37	26.5	19.5	15.75	12.3	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-3	100		95.1	85	77	58	43.5	22.3	11	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-4	98		91.4	76	63	52.5	46.2	28.2	21.4	N/A	N/A	16.3	N/A	Passed	Failed	N/A	N/A
ER-5	97		86.1	76	66	53.5	47.6	31.4	25.9	N/A	N/A	13.3	N/A	Failed	Failed	N/A	N/A
ER-6	100		93	78	64	53.4	46.6	28.9	23.9	N/A	N/A	19.7	N/A	Failed	Failed	N/A	N/A
ER-7	98		88.8	72	58	48.7	42.5	25.2	19.4	N/A	N/A	19.6	N/A	Failed	Failed	N/A	N/A
ER-8	100		100	100	76	56.1	40.5	31.3	22.1	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-9	100		100	100	88	70	42	34	30	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
ER-10	100		100	100	90	72	53	19	12	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
ER-11			95	86	60	50	41	26	18	25	18	7	91	Passed	Passed	Passed	Passed
ER-12			98	94	86	69	39	18	9	21	15	6	134	Failed	Passed	Passed	Passed
ER-13			92	88	76	60	43	26	16	25	14	11	73	Failed	Passed	Passed	Passed
ER-14			95	83	67	45	27	17	10	23	17	6	99	Failed	Passed	Passed	Passed
ER-15			94	80	64	49	29	15	7	26	15	11	105	Failed	Passed	Passed	Passed
ER-16			95	83	72	57	42	21	9	23	11	12	67	Failed	Passed	Passed	Passed
ER-17	100	99		96	81	54	38	30	15	45	23	22	38	Passed	Failed	Failed	Failed
ER-18	100	100		100	87	57	38	30	15	47	23	24	N/A	Passed	Failed	Failed	N/A
ER-19	100	100		98	86	55	37	28	12	43	22	21	N/A	Passed	Failed	Failed	N/A
ER-20	100	95	86	68	45	37	31	25	13	28	16	12	40	Failed	Passed	Passed	Failed

Table G7: Grading, CBR and Atterberg's Limits of natural gravels in the Eastern Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 75 mm	53 mm	37.5 mm	20 mm	10 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98%	Base Specifications: Grading	PI≤ 12	LL≤ 30	CBR≥ 60
ER-21	99	97	93	80	65	54	45	38	33	15	19	13	6	21	Failed	Passed	Passed	Failed
ER-22	98	94	88	72	61	50	42	38	31	16	25	15	10	45	Failed	Passed	Passed	Failed
ER-23	100	99	95	80	61	49	38	35	34	26	40	21	19	21	Failed	Failed	Failed	Failed
ER-24	100	99	96	81	61	46	35	29	22	14	37	21	16	35	Passed	Failed	Failed	Failed

Table G8: Grading, CBR and Atterberg's Limits of natural gravels in the Central Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing 53 mm	37.5 mm	20 mm	13.2 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	Atterberg Test: LL %	PL %	PI %	CBR at 98%	Base Specifications: Grading	PI≤ 12	LL≤ 30	CBR≥ 60
CR-1		100	92	85	78	62	49	26	19	16	13	43.5	26.8	16.7	N/A	Passed	Failed	Failed	N/A
CR-2		100	89	81	74	62	55	41	33	23	15	25.9	15.7	10.2	N/A	Passed	Passed	Passed	N/A
CR-3		100	88	83	77	61	49	31	25	22	18	42.8	29.8	13	N/A	Passed	Failed	Failed	N/A
CR-4		100	89	82	76	65	57	44	40	28	17	22.8	15.4	7.4	N/A	Passed	Passed	Passed	N/A
CR-5		100	77	64	54	42	36	28	24	21	17	33.5	20.2	13.3	N/A	Passed	Failed	Failed	N/A
CR-6		100	92	82	75	64	55	35	26	21	16	33.7	21.7	12	N/A	Passed	Passed	Failed	N/A
CR-7		100	87	82	76	66	60	41	30	20	13	24.7	15.9	8.8	N/A	Passed	Passed	Passed	N/A
CR-8		100	78	69	62	52	47	38	33	29	23	32.1	20	12.1	N/A	Failed	Failed	Failed	N/A
CR-9		100	85	76	68	57	49	35	28	21	14	31.5	18.7	12.8	N/A	Passed	Failed	Failed	N/A
CR-10		100	91	90	78	68	62	48	38	31	23	38.9	20	18.9	N/A	Failed	Failed	Failed	N/A
CR-11		100	94	90	87	78	71	49	38	28	20	30.7	18.4	12.3	N/A	Passed	Failed	Failed	N/A
CR-12		100	92	90	86	78	72	60	51	41	34	38.9	22	16.9	N/A	Failed	Failed	Failed	N/A
CR-13	100	100	90		61		31	24		17	13	N/A	N/A	9	N/A	Passed	Passed	N/A	N/A
CR-14	100	100	97		72		50	37		29	24	N/A	N/A	15	N/A	Failed	Failed	N/A	N/A
CR-15	100	95	74		48		33	25		18	14	N/A	N/A	14	N/A	Failed	Failed	N/A	N/A
CR-16	100	100	91		75		49	34		15	9	N/A	N/A	8	N/A	Passed	Passed	N/A	N/A
CR-17	100	100	87		78		53	38		16	7	N/A	N/A	4	N/A	Passed	Passed	N/A	N/A
CR-18	100	97	92		83		62	34		13	9	N/A	N/A	7	N/A	Passed	Passed	N/A	N/A
CR-19	100	100	96		87		67	44		21	15	N/A	N/A	11	N/A	Passed	Passed	N/A	N/A
CR-20	100	100	89		70		53	41		29.5	18	N/A	N/A	8.6	N/A	Passed	Passed	N/A	N/A

Table C8: Grading, CBR and Atterberg's Limits of natural gravels in the Central Region to Base Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	75	53	37.5	20	10	4.75	2.36	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
CR-21		100	58	81	64	50	36	18	17	N/A	N/A	14	N/A	Passed	Failed	N/A	N/A
CR-22		100	58	86	76	58	45	25	24	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
CR-23		100	100	100	93	79	40	17.5	11.5	N/A	N/A	11.8	N/A	Failed	Passed	N/A	N/A
CR-24		100	100	100	89	66	54	37.75	21.5	N/A	N/A	19.1	N/A	Failed	Failed	N/A	N/A
CR-25		100	100	100	81	58	39	22.9	17	N/A	N/A	12.9	N/A	Passed	Failed	N/A	N/A
CR-26		100	100	94	88	72	52	31.5	8.5	N/A	N/A	4.2	N/A	Passed	Passed	N/A	N/A
CR-27	100		95	91	84	69	43	21	11	23	12	11	106	Passed	Passed	Passed	Passed
CR-28	99		95	90	83	70	40	22	15	35	17	19	60	Passed	Failed	Failed	Failed
CR-29	100		96	91	81	69	43	22	15	29	14	15	50	Passed	Failed	Passed	Passed
CR-30	98		93	91	83	67	40	20	9	23	10	13	63	Passed	Failed	Passed	Failed
CR-31	99		96	94	86	65	35	20	10	25	11	14	67	Passed	Failed	Passed	Failed
CR-32	100		95	89	78	73	39	22	9	20	10	10	237	Passed	Passed	Passed	Passed
CR-33	100		99	97	90	76	42	23	12	27	12	15	99	Failed	Failed	Passed	Passed
CR-34	100		97	94	85	62	27	14	5	11	5	6	139	Passed	Passed	Passed	Passed
CR-35	100		98	95	83	62	38	19	9	17	9	8	101	Passed	Passed	Passed	Passed
CR-36	100		97	93	88	73	44	26	12	10	5	5	129	Passed	Passed	Passed	Passed
CR-37	99		95	86	76	57	32	20	13	34	13	21	72	Passed	Failed	Failed	Failed
CR-38	99		93	87	78	52	44	36	29	61	24	37	10	Failed	Failed	Failed	Failed
CR-39	100	100	97	91	85	70	30	12	7	28	14	14	42	Passed	Failed	Failed	Failed
CR-40	100		97	92	82	64	46	37	35	65	29	36	14	Failed	Failed	Failed	Failed

Table C8: Grading, CBR and Atterberg's Limits of natural gravels in the Central Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing											Atterberg Test			CBR at 98%	Base Specifications			
	75	53	37.5	20	10	6.7	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
CR-41	100		93	89	82		67	47		24	20	28	12	16	112	Passed	Failed	Passed	Passed
CR-42	100	99	97	93	88		65	48	40	38	30	43	23	20	34	Failed	Failed	Failed	Failed
CR-43	100	100	96	85	70		57	38	34	30	21	35	17	18	36	Passed	Failed	Failed	Failed
CR-44	100	100	98	94	87		66	34	31	30	26	53	28	25	47	Failed	Failed	Failed	Failed
CR-45	100	100	98	92	64		46	45	36	34	25	42	21	19	15	Failed	Failed	Failed	Failed
CR-46	100	96	91	78	47		36	52	30	26	18	30	16	14	20	Passed	Failed	Failed	Failed
CR-47	100	100	92	84	56		38	26	23	22	20	62	27	35	26	Passed	Failed	Failed	Failed
CR-48	100	100	98	92	80		56	34	28	27	22	37	23	14	28	Passed	Failed	Failed	Failed
CR-49	100	100	96	85	62		46	39	37	33	26	44	21	23	38	Failed	Failed	Failed	Failed
CR-50	100	84	80	70	53		43	33	29	28	23	43	27	16	27	Failed	Failed	Failed	Failed
CR-51	100	100	96	86	66		46	31	23	20	15	42	23	19	20	Passed	Failed	Failed	Failed
CR-52	100	83	80	67	55		42	33	29	27	20	41	21	20	23	Failed	Failed	Failed	Failed
CR-53	100	99	96	88	63		40	21	13	8	1	36	19	16	74	Failed	Failed	Failed	Passed
CR-54	100	100	94	84	69		51	37	27	27	11	34	13	11	51	Passed	Passed	Failed	Failed
CR-55		100	98	90	69	59	50	33	24	16	5	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
CR-56		100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A

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Table G9: Grading, CBR and Atterberg's Limits of natural gravels in the Volta Region compared to Base specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	53	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
VR-1	100	98	85		58	44		25	14	N/A	N/A	8.8	N/A	N/A	Passed	N/A	N/A
VR-2	100	96	61		29	19		11	9	N/A	N/A	8.8	N/A	Failed	Passed	N/A	N/A
VR-3	100	92	74		52	41		26	14	N/A	N/A	7	N/A	Failed	Passed	N/A	N/A
VR-4	100	100	93		64	56		28	22	N/A	N/A	14.7	N/A	Failed	Failed	N/A	N/A
VR-5	100	100	65		44	25		17	10	N/A	N/A	6.1	N/A	Failed	Passed	N/A	N/A
VR-6	100	100	72		52	38		21	13	N/A	N/A	4.3	N/A	Failed	Passed	N/A	N/A
VR-7	100	100	93		74	79		52	13	N/A	N/A	4.3	N/A	Failed	Passed	N/A	N/A
VR-8	100	100	70		52.5	36		23	18	N/A	N/A	9	N/A	Failed	Passed	N/A	N/A
VR-9	100	100	87		61	43		28	22	N/A	N/A	7.7	N/A	Passed	Passed	N/A	N/A
VR-10	100	96	84		60	51		29	16	N/A	N/A	6.2	N/A	Passed	Passed	N/A	N/A
VR-11	100	91	78		57	53		26	14	N/A	N/A	7.4	N/A	Passed	Passed	N/A	N/A
VR-12		99	98	68	29	24	22		14	39	22	17	50	Failed	Failed	Failed	Failed
VR-13			100	69	33	26	23		14	45	24	21	45	Passed	Failed	Failed	Failed
VR-14		100	99	71	38	20	17		8	40	25	15	55	Failed	Failed	Failed	Failed
VR-15			100	81	44	25	17		14	33	18	15	64	Passed	Failed	Failed	Passed
VR-16		100	98	86	47	24	20		12	28	17	11	60	Passed	Passed	Passed	Passed
VR-17		100	97	87	56	38	32		18	23	15	8	50	Passed	Passed	Passed	Failed
VR-18		100	98	86	57	3	33		14	21	14	7	70	Failed	Passed	Passed	Passed
VR-19		100	97	86	34	17	12		4	25	19	6	50	Failed	Passed	Passed	Failed
VR-20		100		73	36	16	12		6	28	18	10	57	Failed	Passed	Passed	Failed

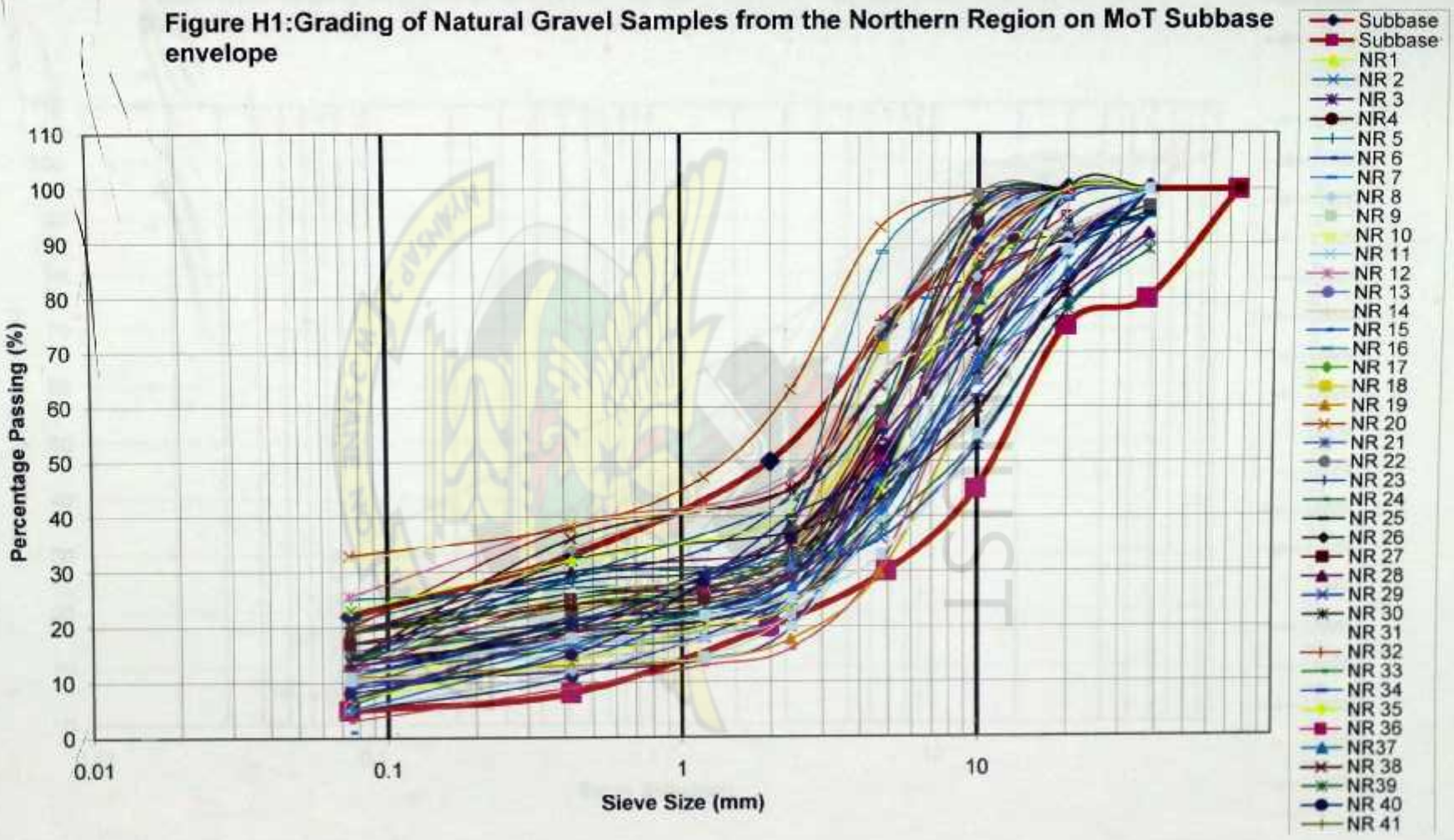
Table G9: Grading, CBR and Atterberg's Limits of natural gravels in the Volta Region compared to Base Specifications

Sample Identification	Grading: Percentage Passing									Atterberg Test			CBR at 98%	Base Specifications			
	53	37.5	20	10	4.75	2.36	1.2	0.425	0.075	LL	PL	PI					
	mm	mm	mm	mm	mm	mm	mm	mm	mm	%	%	%	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
VR-21	100		87	72	46	32	26		12	33	16	17	43	Passed	Failed	Failed	Failed
VR-22		100	99	77	48	32	27		18	46	26	20	45	Passed	Failed	Failed	Failed
VR-23			100	69	33	23	20		13	38	22	16	50	Passed	Failed	Failed	Failed
VR-24		99	98	63	29	21	17		12	39	21	18	40	Passed	Failed	Failed	Failed
VR-25			93			41		35	25	23	13	10	76	Failed	Passed	Passed	Passed
VR-26			100			43		27	7	21	20	1	168	Passed	Passed	Passed	Passed
VR-27			100			51		32	20	20	14	6	98	Passed	Passed	Passed	Passed
VR-28			100			43		34	23	23	17	6	66	Failed	Passed	Passed	Passed
VR-29			100			28		23	15	19	15	4	94	Passed	Passed	Passed	Passed
VR-30			99			33		26	21	20	14	6	96	Passed	Passed	Passed	Passed
VR-31			99			40		28	22	28	20	8	148	Passed	Passed	Passed	Passed
VR-32			99			36		25	20	27	20	7	98	Passed	Passed	Passed	Passed
VR-33			99			43		28	19	17	14	3	88	Passed	Passed	Passed	Passed
VR-34			99			37		33	24	19	13	6	60	Failed	Passed	Passed	Passed
VR-35			99			31		25	21	21	14	7	82	Passed	Passed	Passed	Passed
VR-36			99			27		22	16	20	4	16	81	Passed	Failed	Passed	Passed
VR-37			100			29		25	19	19	16	3	130	Passed	Passed	Passed	Passed
VR-38			100			43		31	21	19	16	3	53	Passed	Passed	Passed	Failed
VR-39			99			42		37	25	20	15	5	100	Failed	Passed	Passed	Passed

Table G10: Grading, CBR and Atterberg's Limits of natural gravels in the Greater Accra Region compared to Base specifications

Sample Identification	Grading (Percentage Passing)										Atterberg Test			CBR at 98%	Base Specifications			
	53 mm	37.5 mm	20 mm	10 mm	6.7 mm	4.75 mm	2.36 mm	1.2 mm	0.425 mm	0.075 mm	LL %	PL %	PI %	%	Grading	PI≤ 12	LL≤ 30	CBR≥ 60
GAR-1	100		98	79		59	41	33	27	18	22	12	10	80	Passed	Passed	Passed	Passed
GAR-2	100		100	91		62	39	31	25	14	20	14	6	N/A	Failed	Passed	Passed	N/A
GAR-3	100		100	81		57	37	32	28	16	19	12	7	N/A	Failed	Passed	Passed	N/A
GAR-4	100		93	70		54	46	43	38	22	18	11	7	50	Failed	Passed	Passed	Failed
GAR-5	100		99	97		81	52	41	33	20	29	16	13	22	Failed	Failed	Failed	Failed
GAR-6	100		100	96		68	41	33	26	16	23	12	11	N/A	Failed	Passed	Passed	N/A
GAR-7	100		100	91		72	39	28	21	14	24	13	11	N/A	Failed	Passed	Passed	N/A
GAR-8	100		100	95		77	48	37	31	19	24	11	13	N/A	Failed	Failed	Passed	N/A
GAR-9	100		98	83		58	43	39	33	17	22	9	13	50	Passed	Failed	Passed	Failed
GAR-10	100		100	89		70	37	27	19	11	20	10	10	N/A	Passed	Passed	Passed	N/A
GAR-11	99		91	77		58	36	29	22	14	28	15	13	50 N/A	Passed	Failed	Passed	Failed
GAR-12	100		98	92		73	48	33	26	17	22	12	10	N/A	Failed	Passed	Passed	N/A
GAR-13	100		95	87		68	42	30	24	15	24	13	11	N/A	Passed	Passed	Passed	N/A
GAR-14	100		96	80		59	38	32	24	15	19	11	8	N/A	Passed	Passed	Passed	N/A
GAR-15	100		97	87		67	38	28	21	12	24	14	10	70	Passed	Passed	Passed	Passed
GAR-16		96	85	67	53	46	34	24	15	8	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-17	100	98	92	68	51	44	34	30	25	15	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-18			100	96	83	74	52	42	33	19	N/A	N/A	N/A	N/A	Failed	N/A	N/A	N/A
GAR-19	100	93	78	55	42	37	27	21	16	7	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-20	100	97	87	69	54	45	35	31	23	12	N/A	N/A	N/A	N/A	Passed	N/A	N/A	N/A
GAR-21		97	92	83		68	43		17	9	19	15	4	N/A	Passed	Passed	Passed	N/A

Figure H1:Grading of Natural Gravel Samples from the Northern Region on MoT Subbase envelope



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Figue H2:Grading of Natural Gravel Samples from the Upper West Region on MoT Subbase envelope

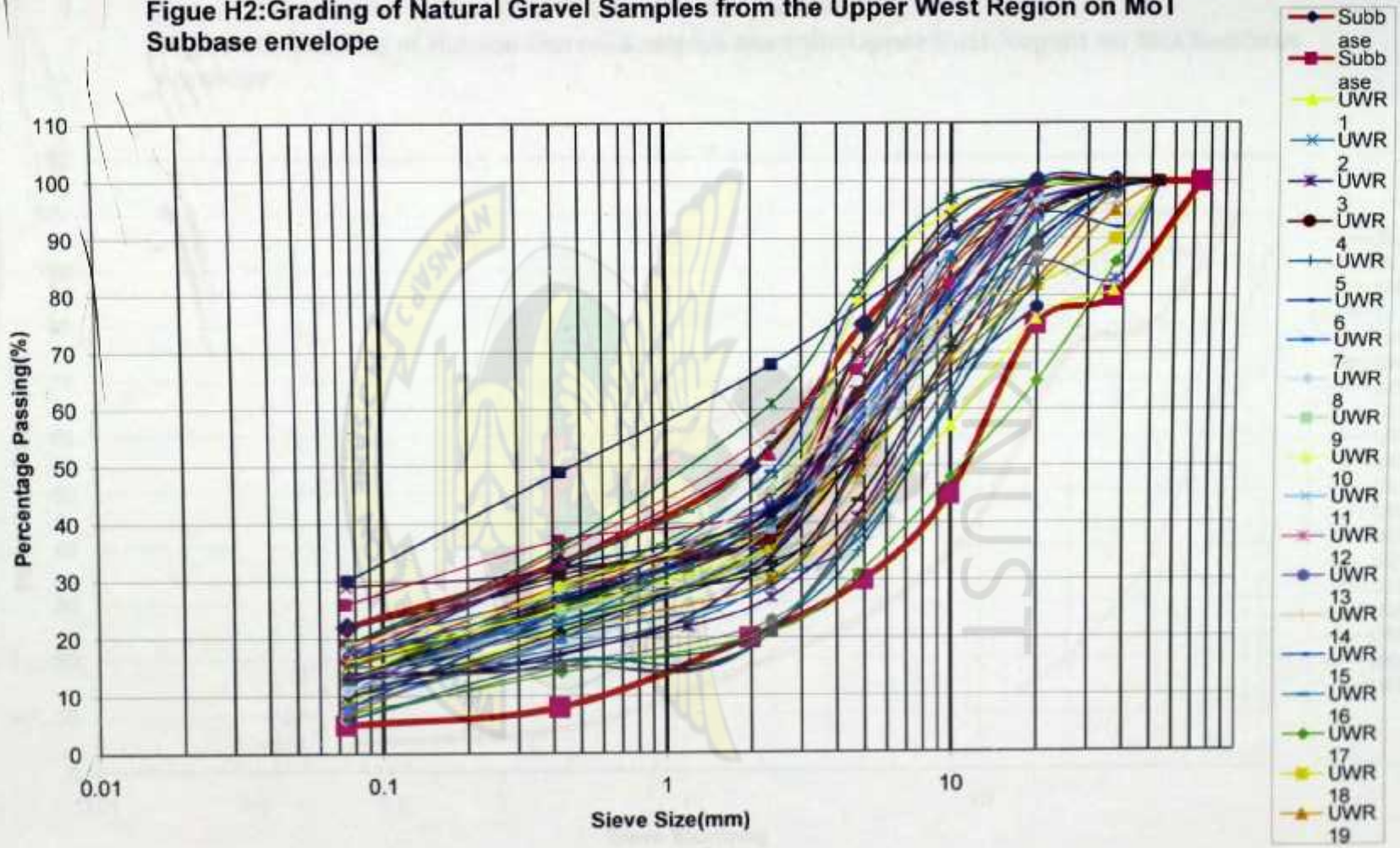


Figure H3:Grading of Natural Gravel Samples from the Upper East Region on Mot Subbase envelope

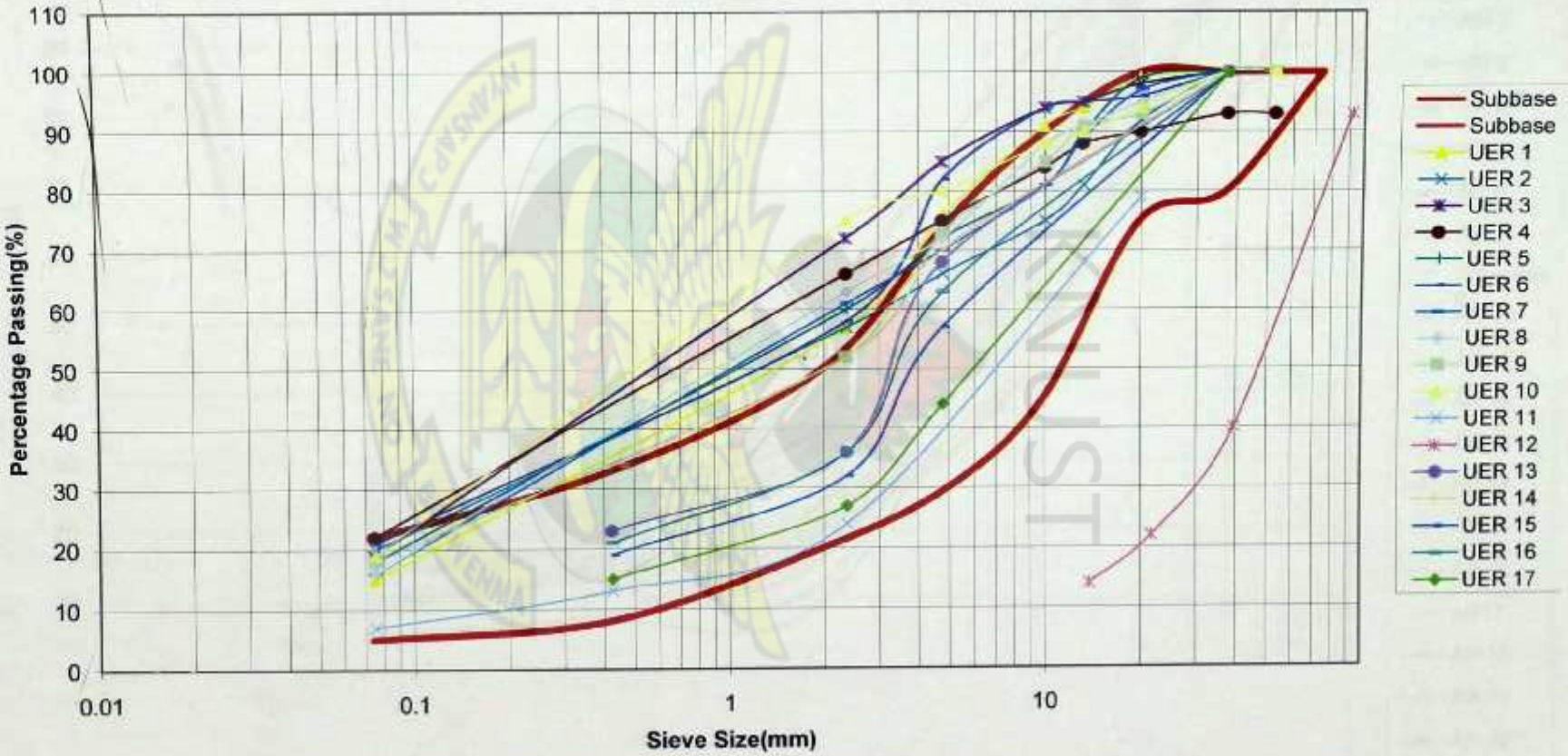


Figure H4:Grading of Natural Samples from the Ahanti Region on MoT Subbase envelope

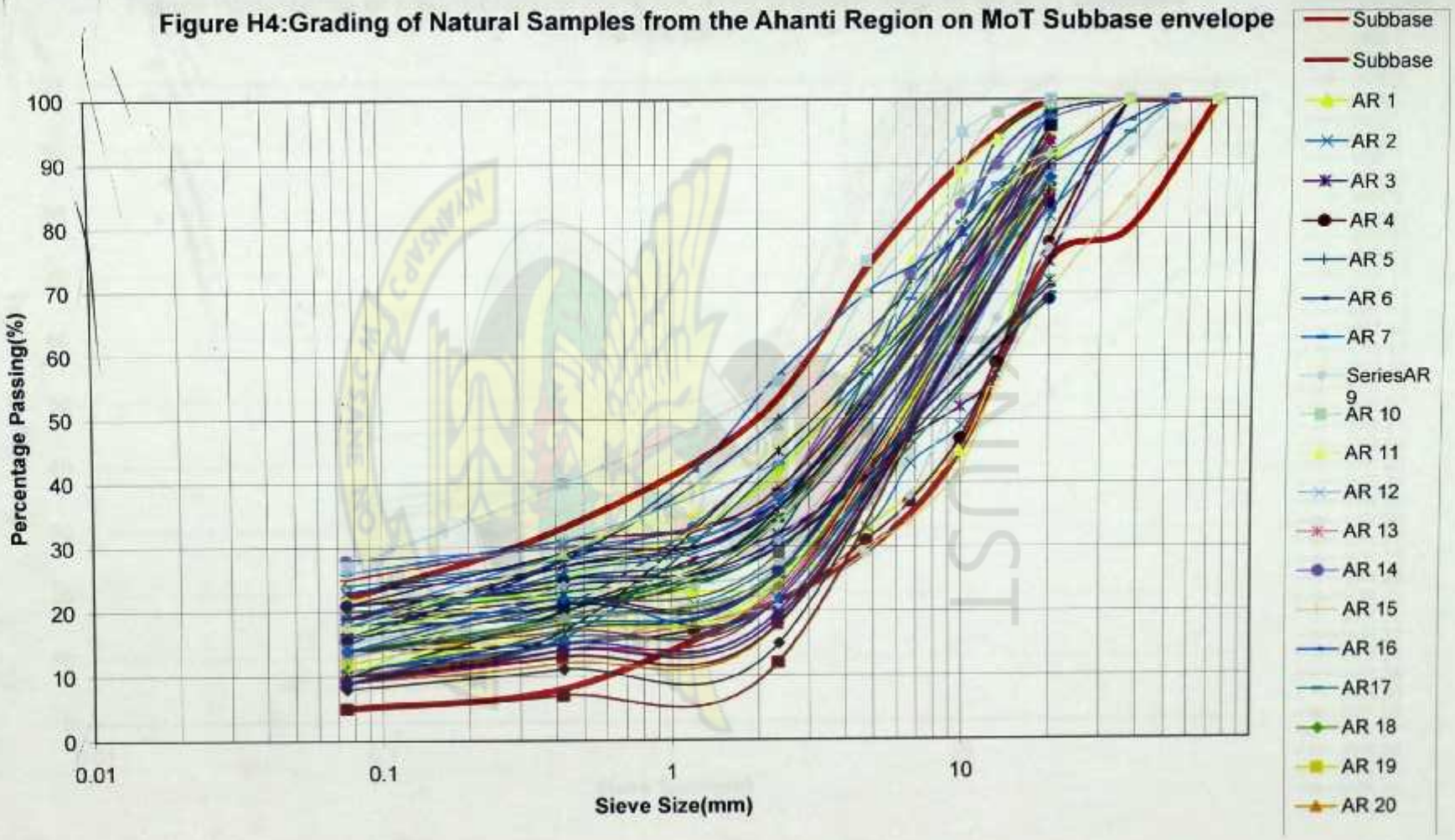


Figure H5:Grading of Natural Gravel Samples from Western Region on MoT Subbase envelope

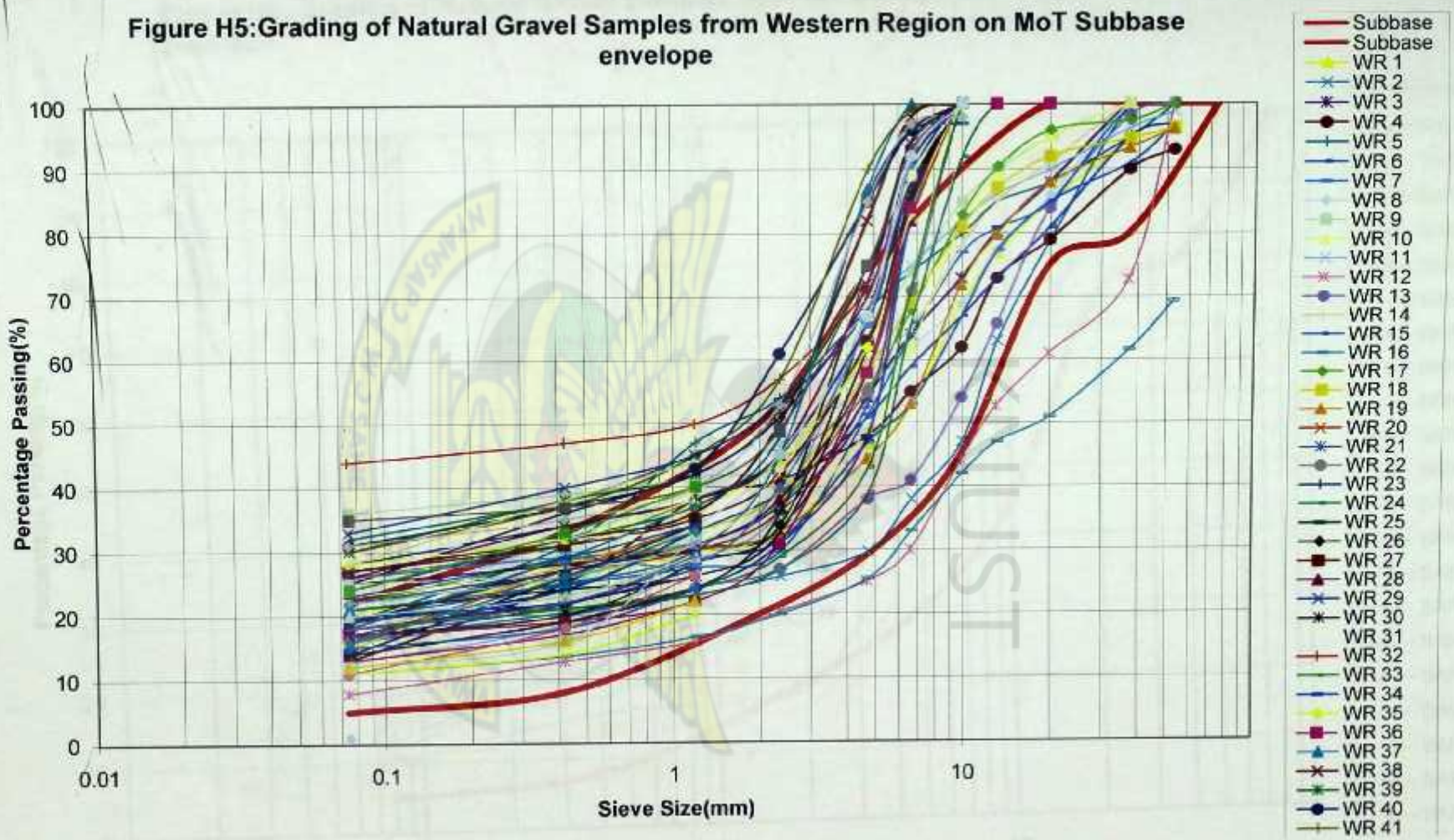


Figure H6: Grading of Natural Gravel Samples from the Brong Ahafo Region on MoT Subbase envelope

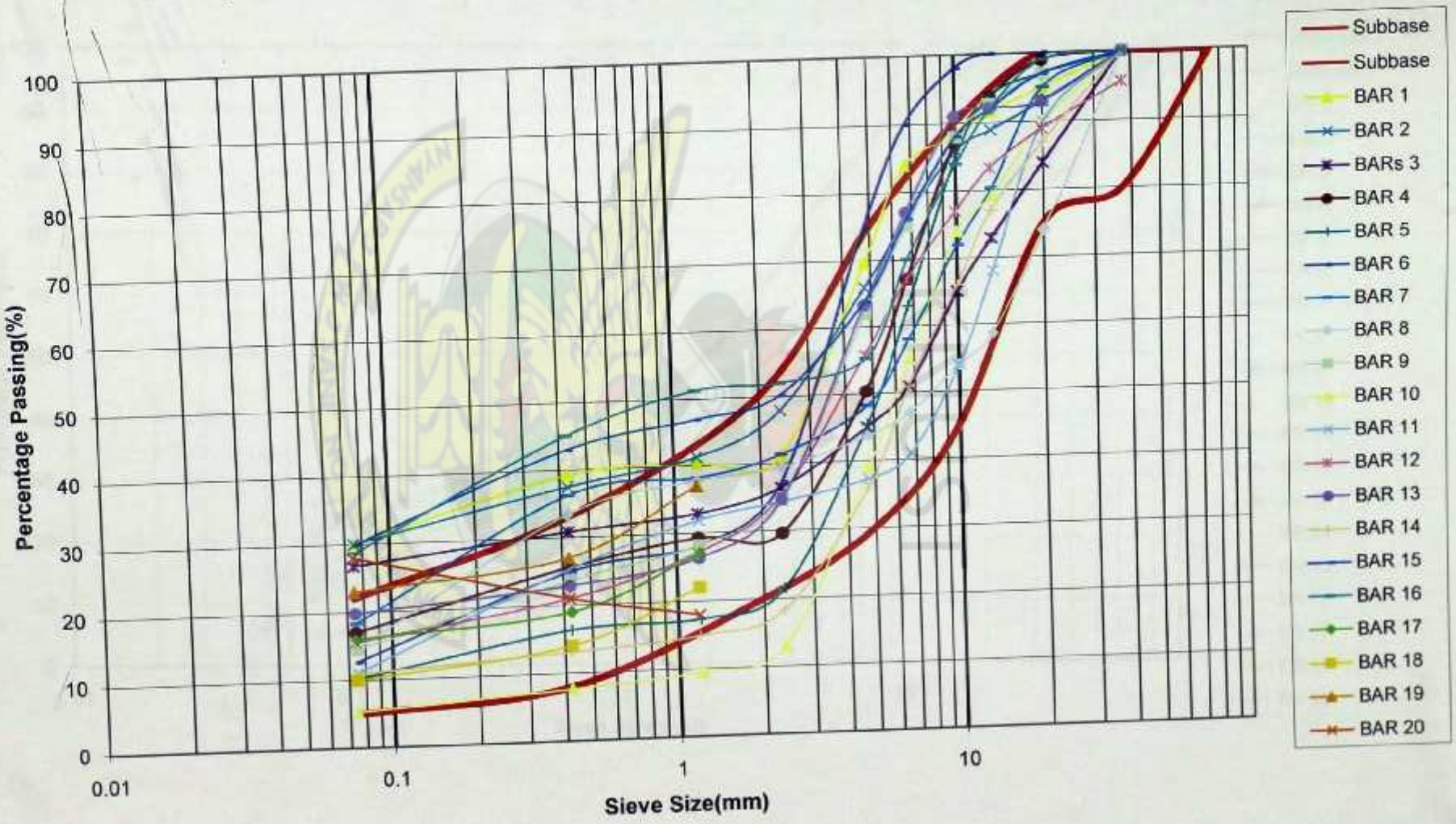


Figure H7:Grading of Natural Samples from Eastern Region on MoT Subbase envelope

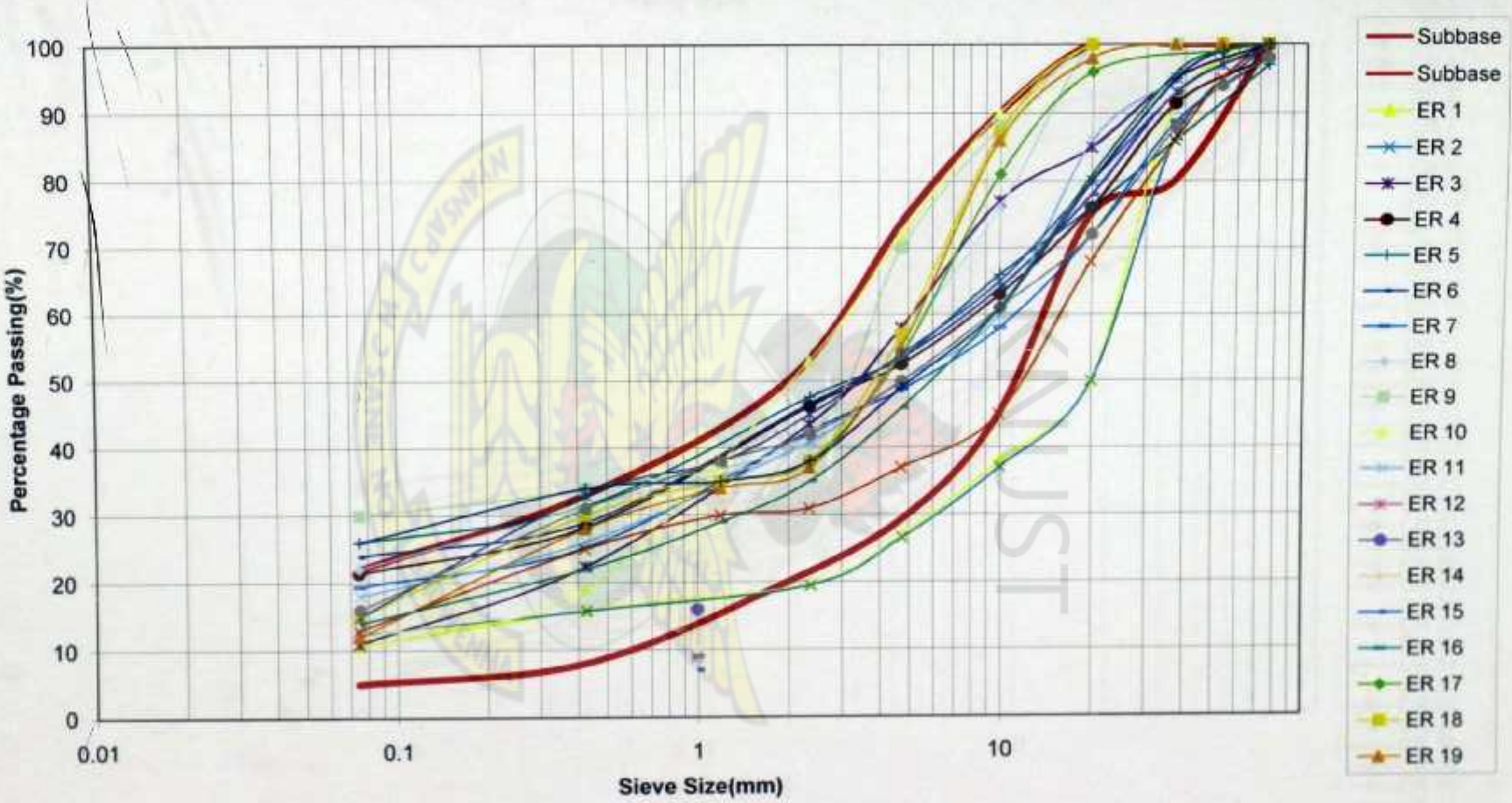


Figure H8:Grading of Natural Gravel Samples in the Central Region on MoT Subbase envelope

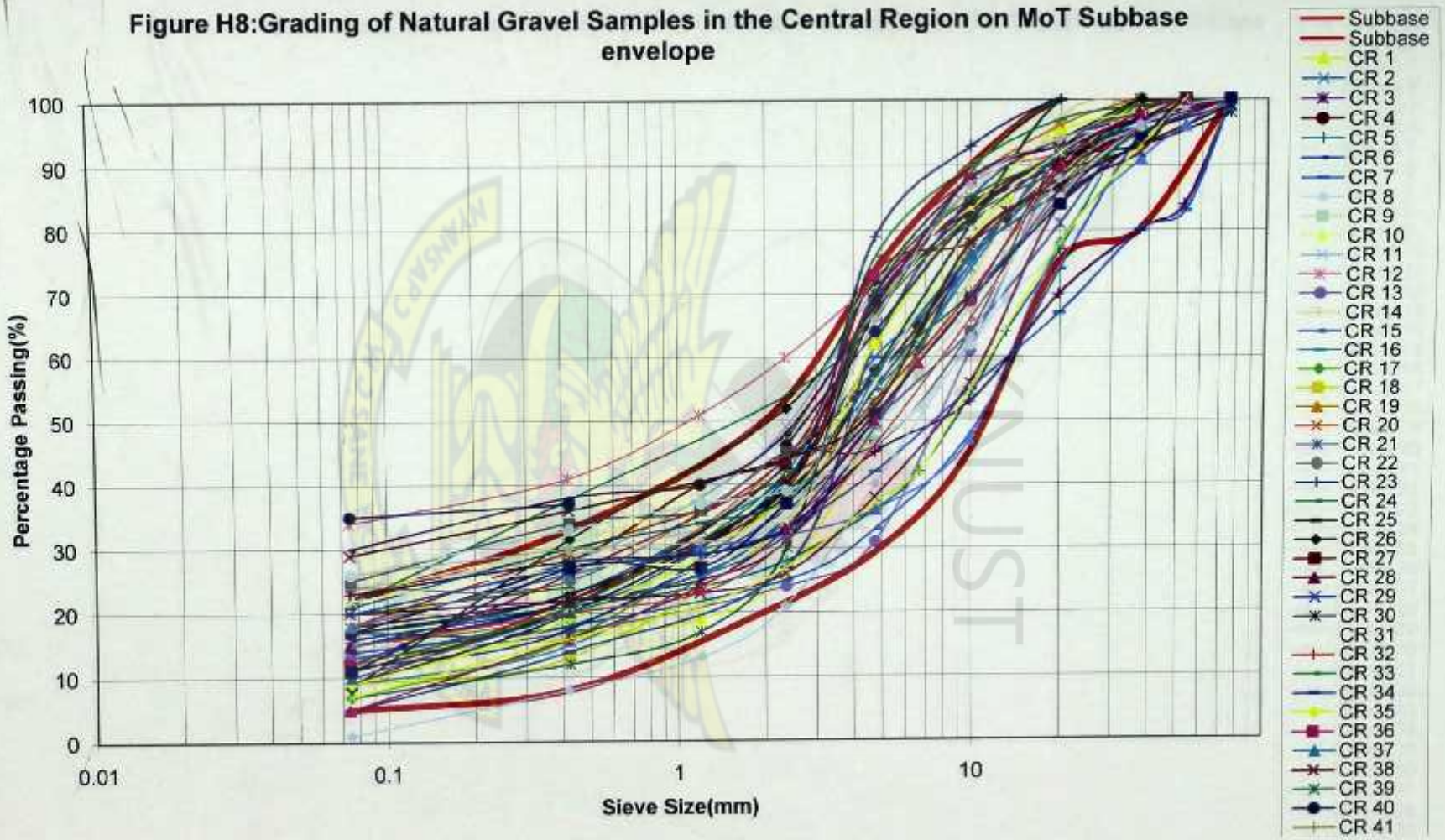
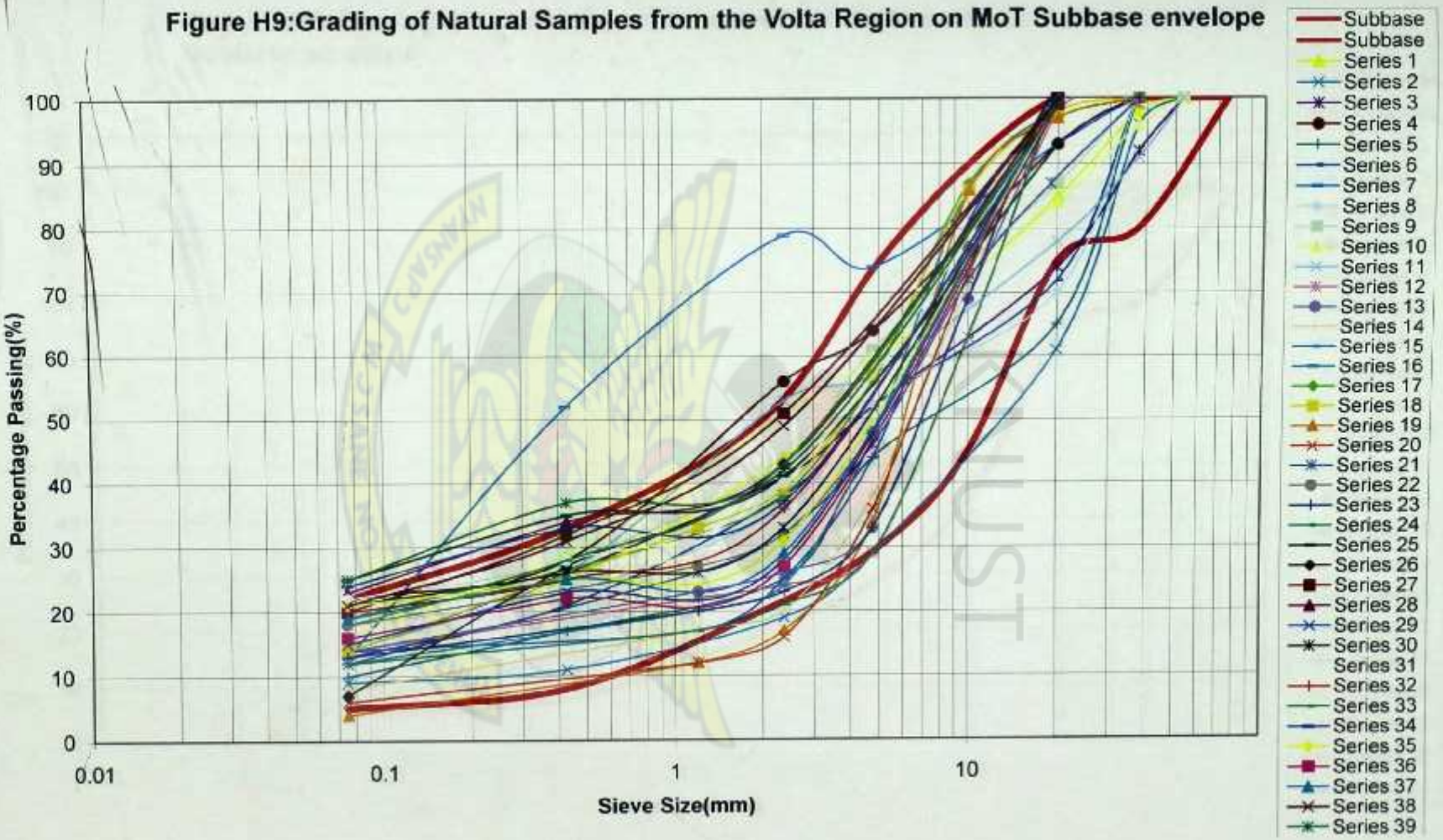


Figure H9:Grading of Natural Samples from the Volta Region on MoT Subbase envelope



Gigure H10:Grading of Natural Gravel Samples from the Greater Accra Region on MoT Subbase envelope

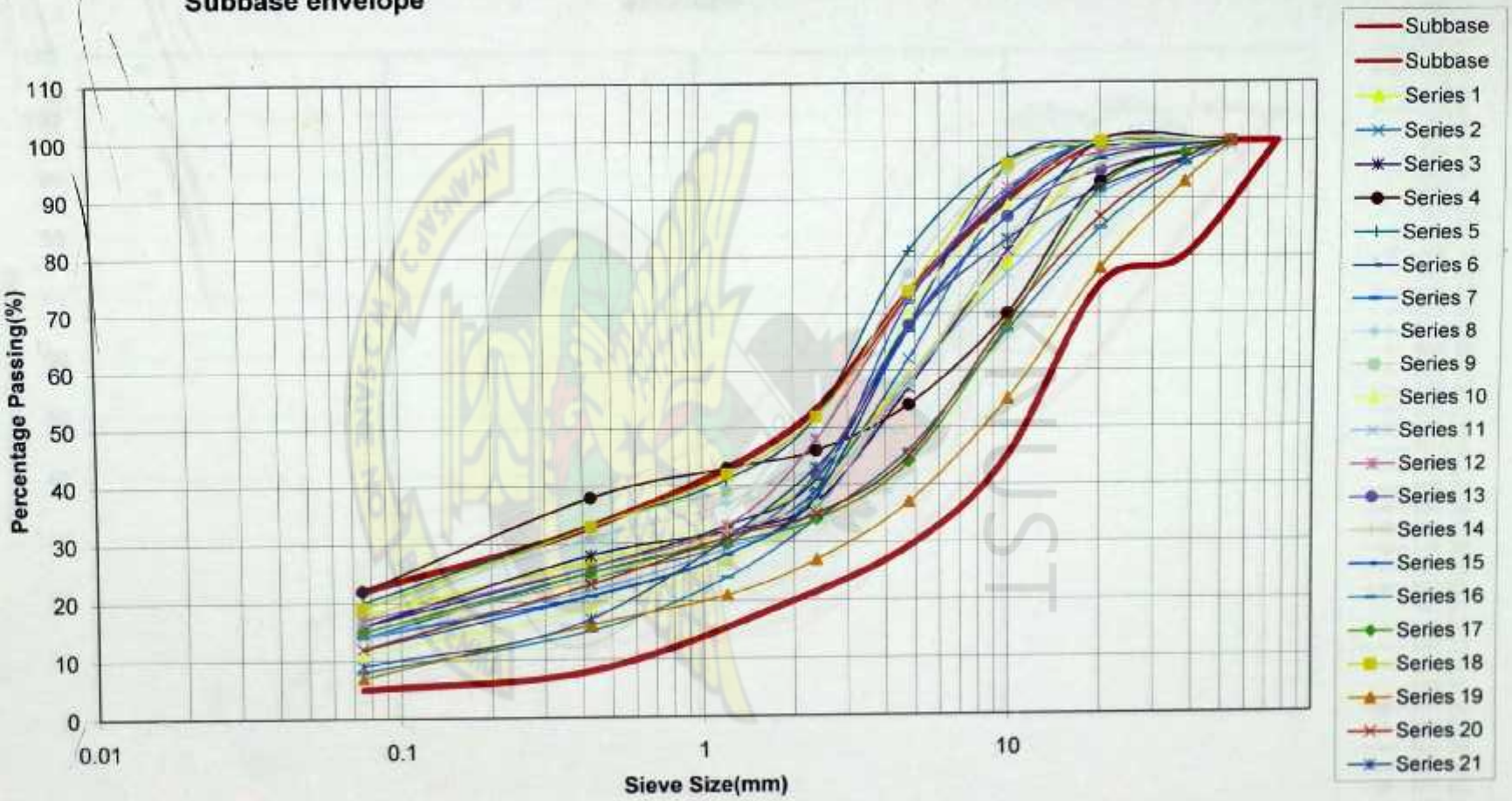


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Figure 11:Grading of Natural Gravel Samples from the Northern Region on MoT Base envelope

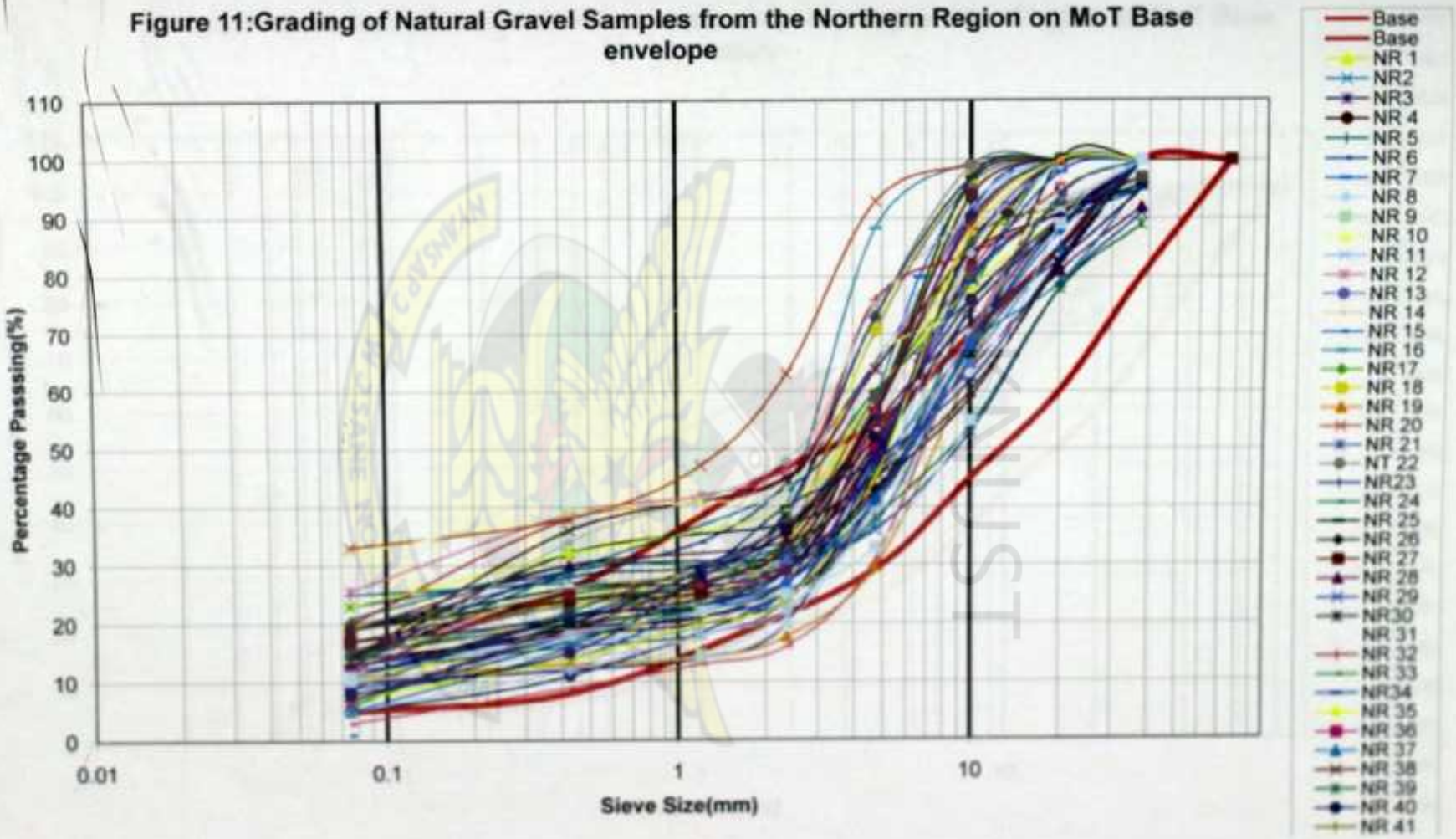

Figure 12:Grading of Natural Gravel Samples from the Upper Wesr Region on MoT Base envelope

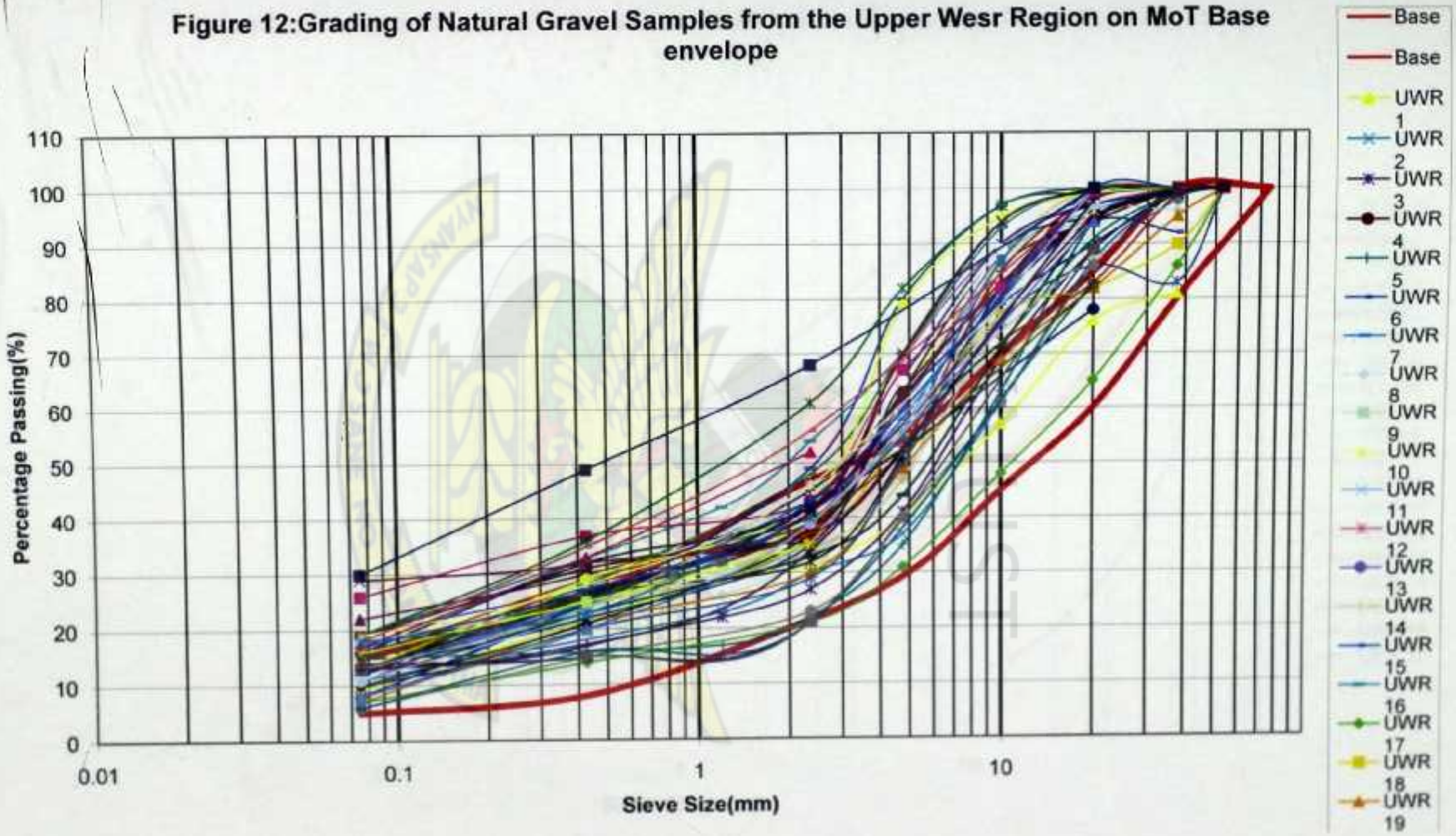

Figure 13:Grading of Natural Gravel Samples from the Upper East Region on MoT Base envelope

Figure 14:Grading of Natural Gravel Samples from the Ashanti Region on MoT Base envelope

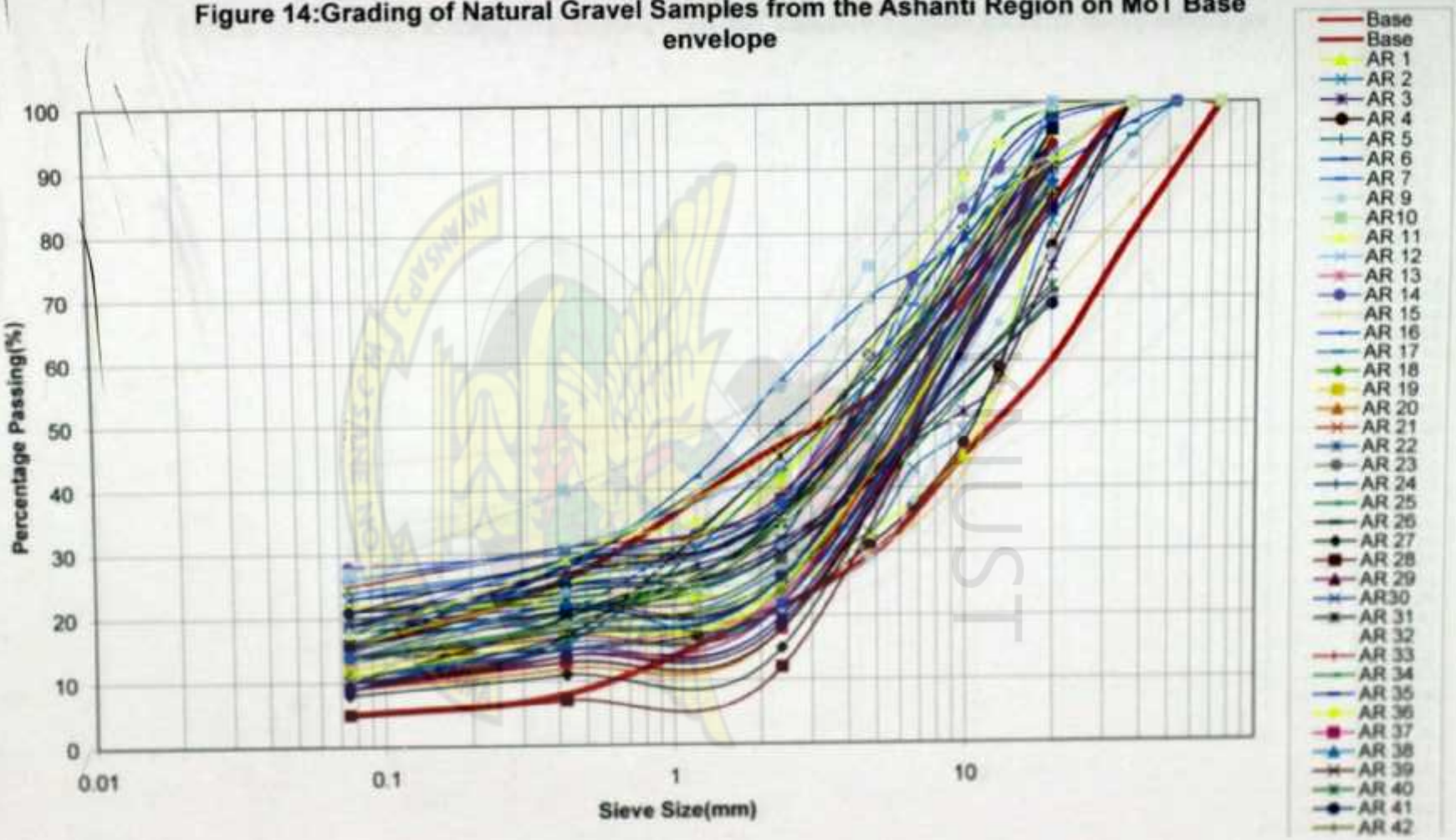

Figure 15:Grading of Natural Samples from the Western Region on MoT Base envelope

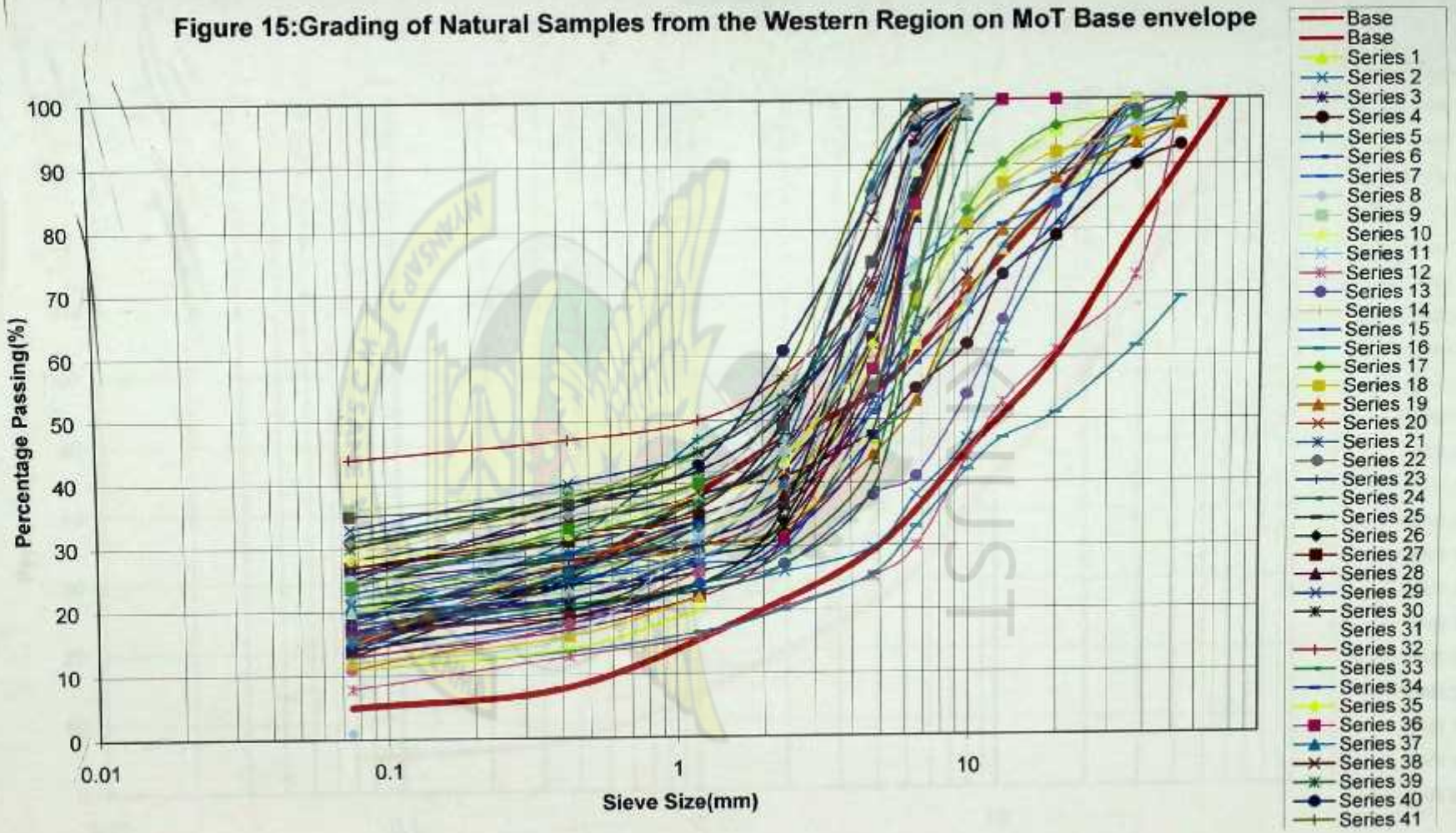

Figure I6:Grading of Natural Gravel Samples from the Brong Ahafo Region on MoT Base envelope

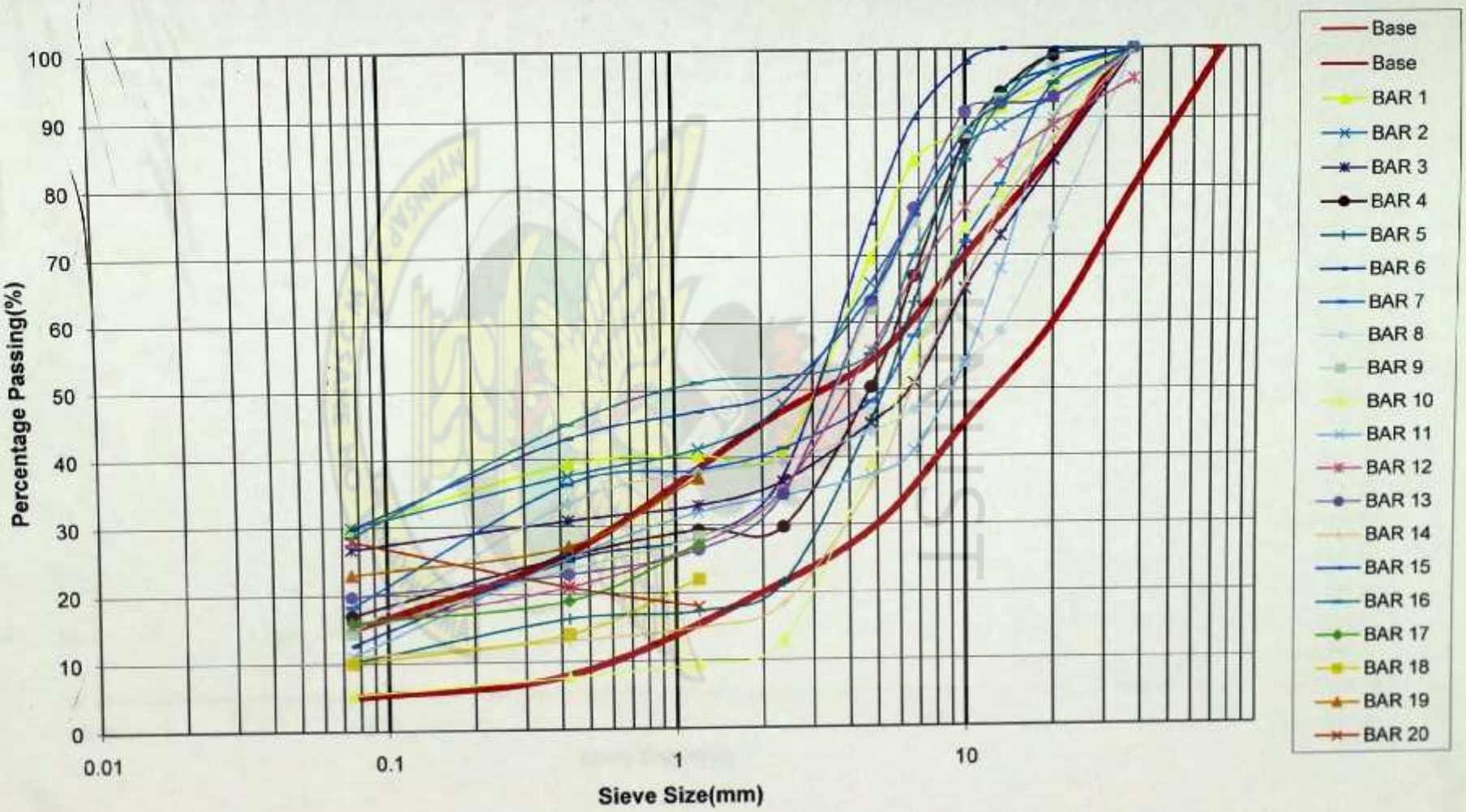

Figure I7:Grading of Natural Gravel Samples from the Eastern Region on MoT Base envelope

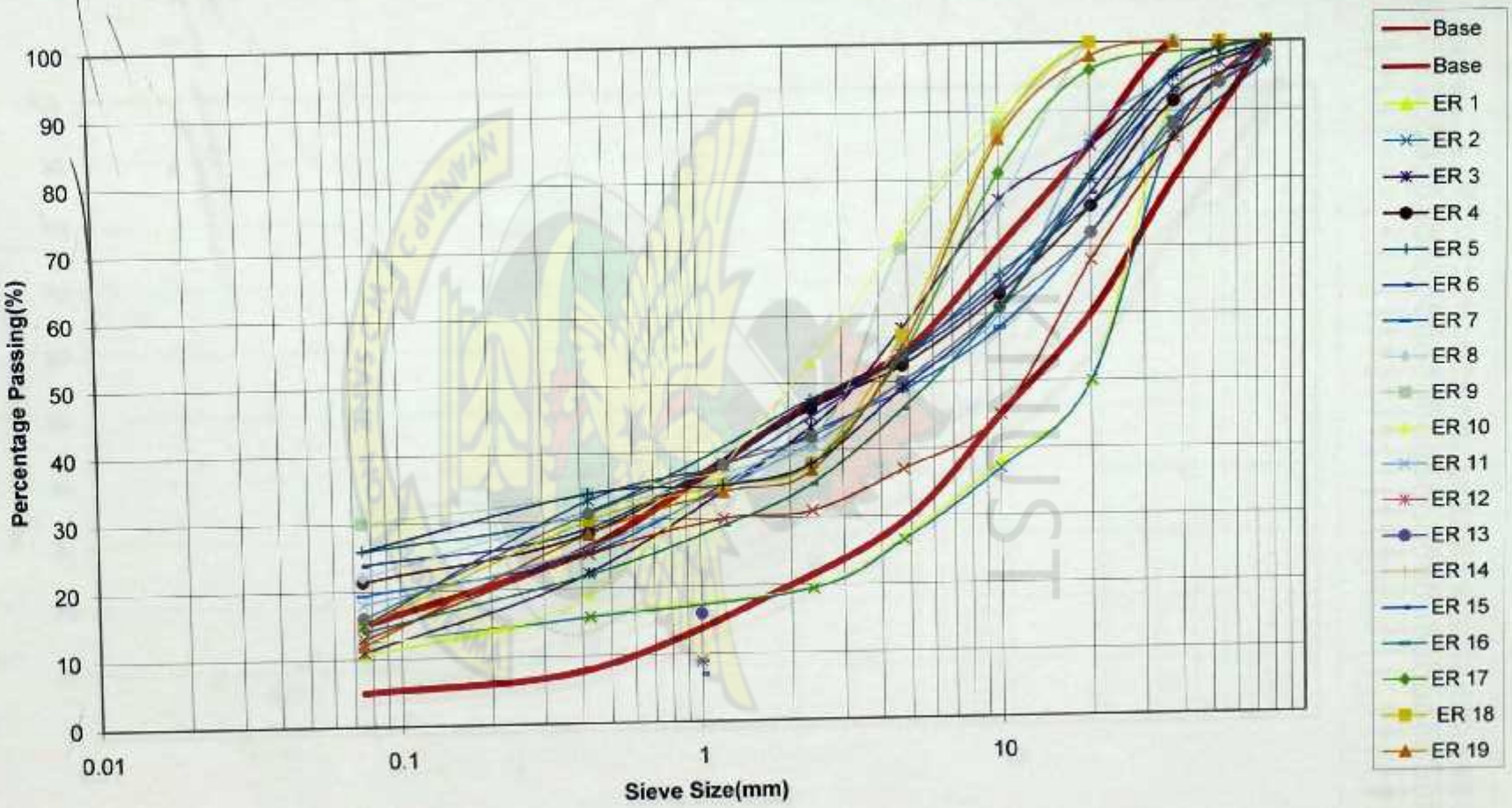

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Figure I8:Grading of Natural Samples from the Central Region on MoT Base envelope

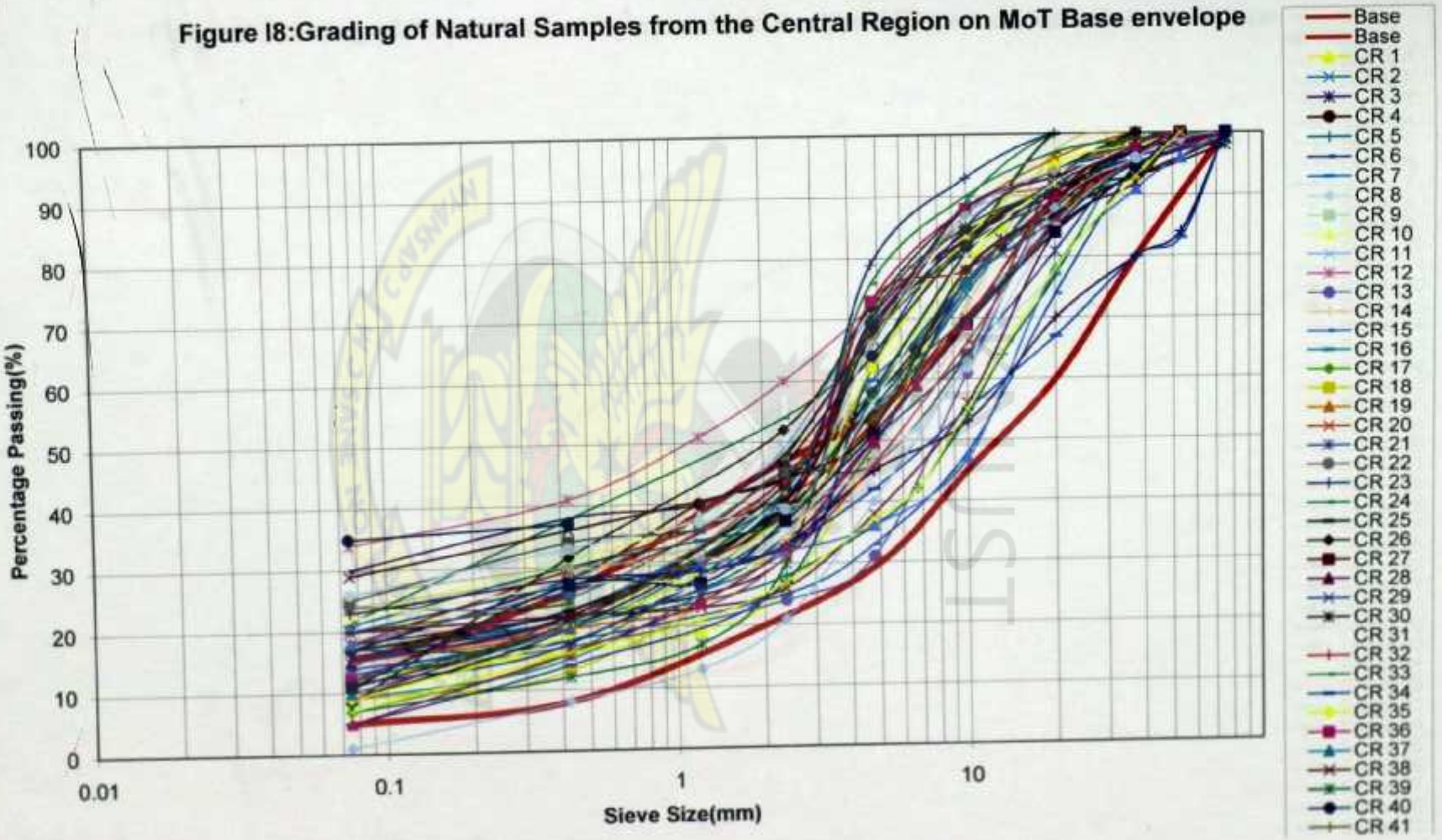

Figure I9:Grading of Natural Gravel Samples from the Volta Region on MoT Base envelope

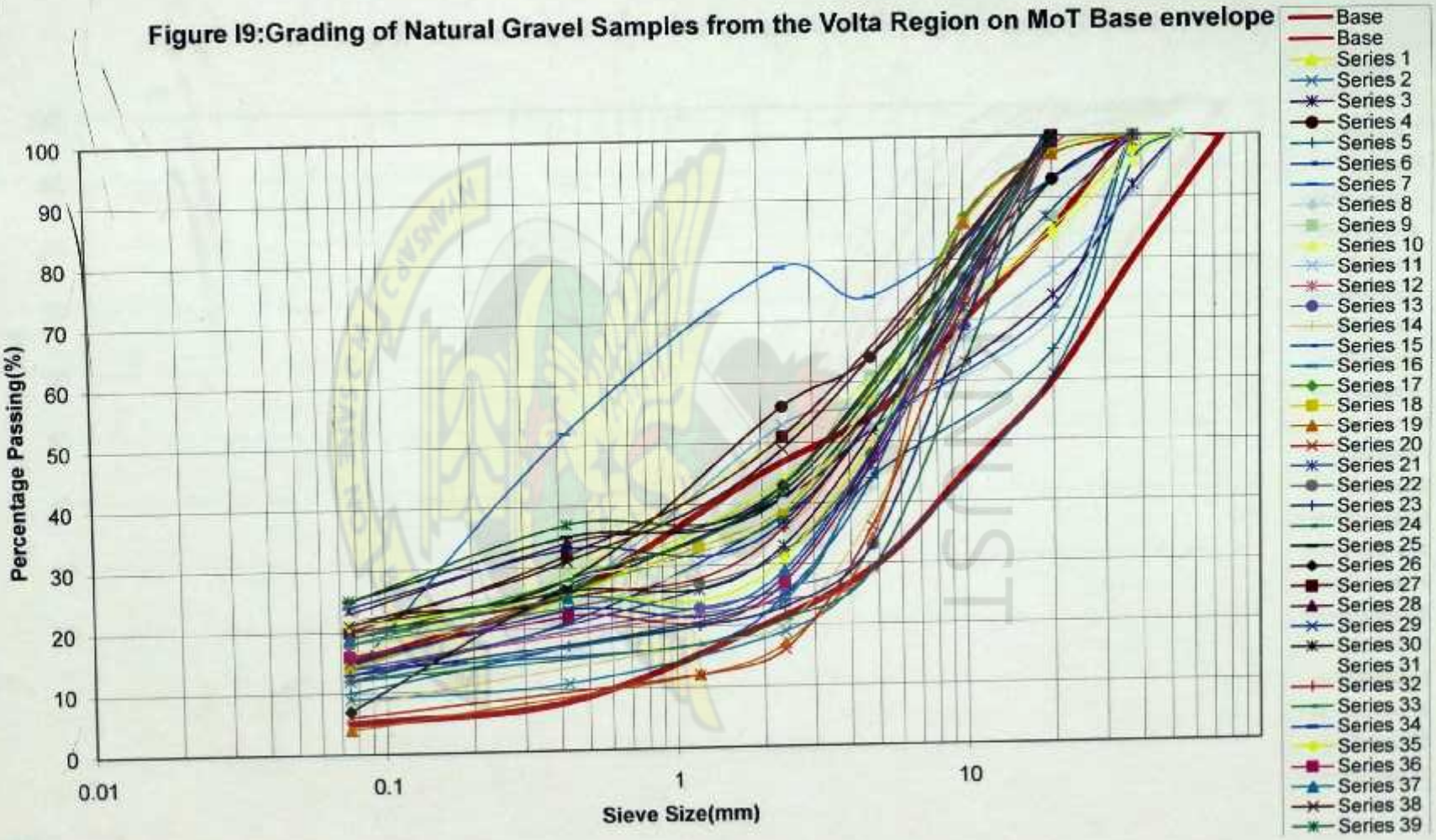

Figure I10:Grading of Natural Gravel from the Greater Accra Region on MoT Base envelope

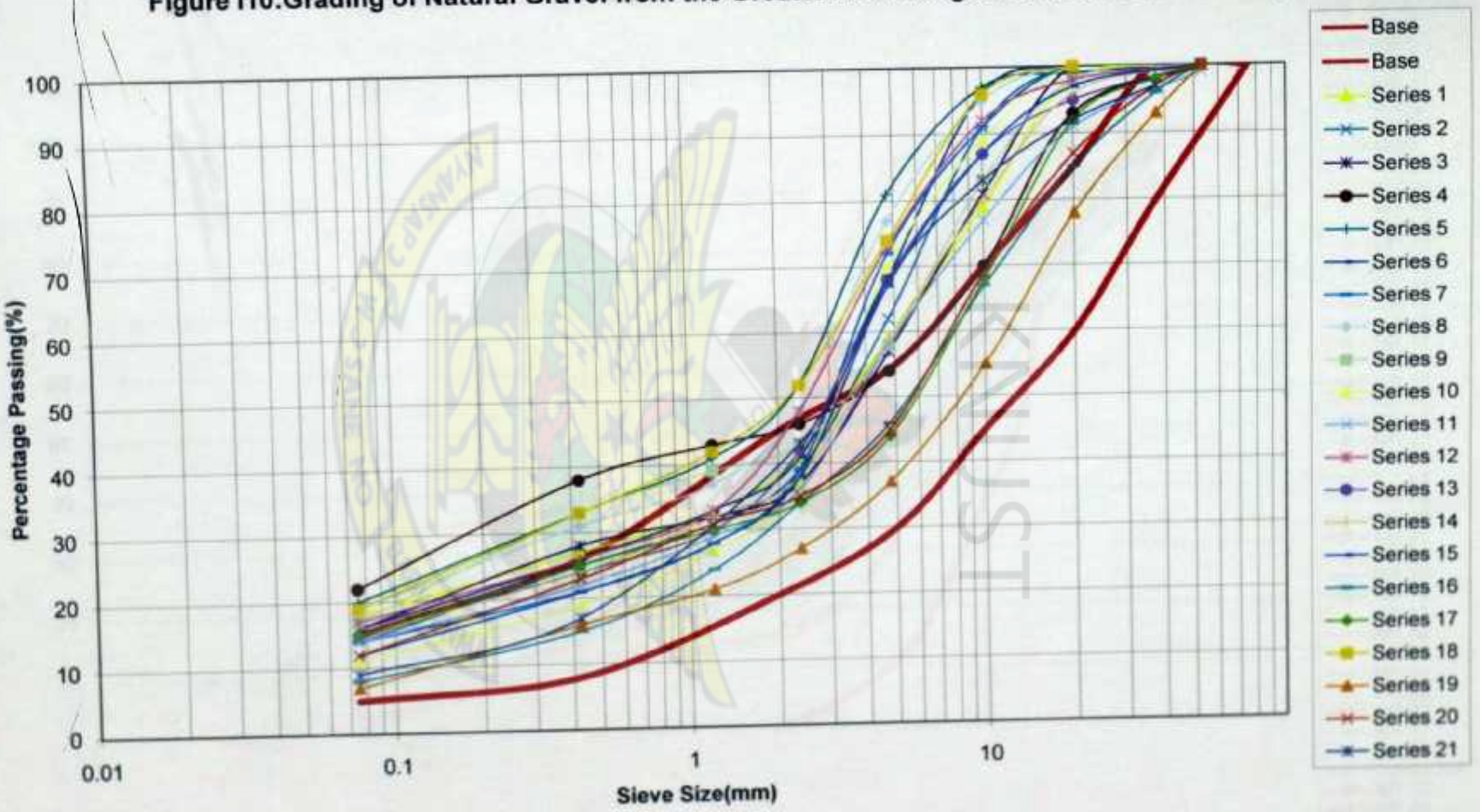

Figure J1:Grading of Natural Gravel Samples in the Northern Region on Otta Seal envelope

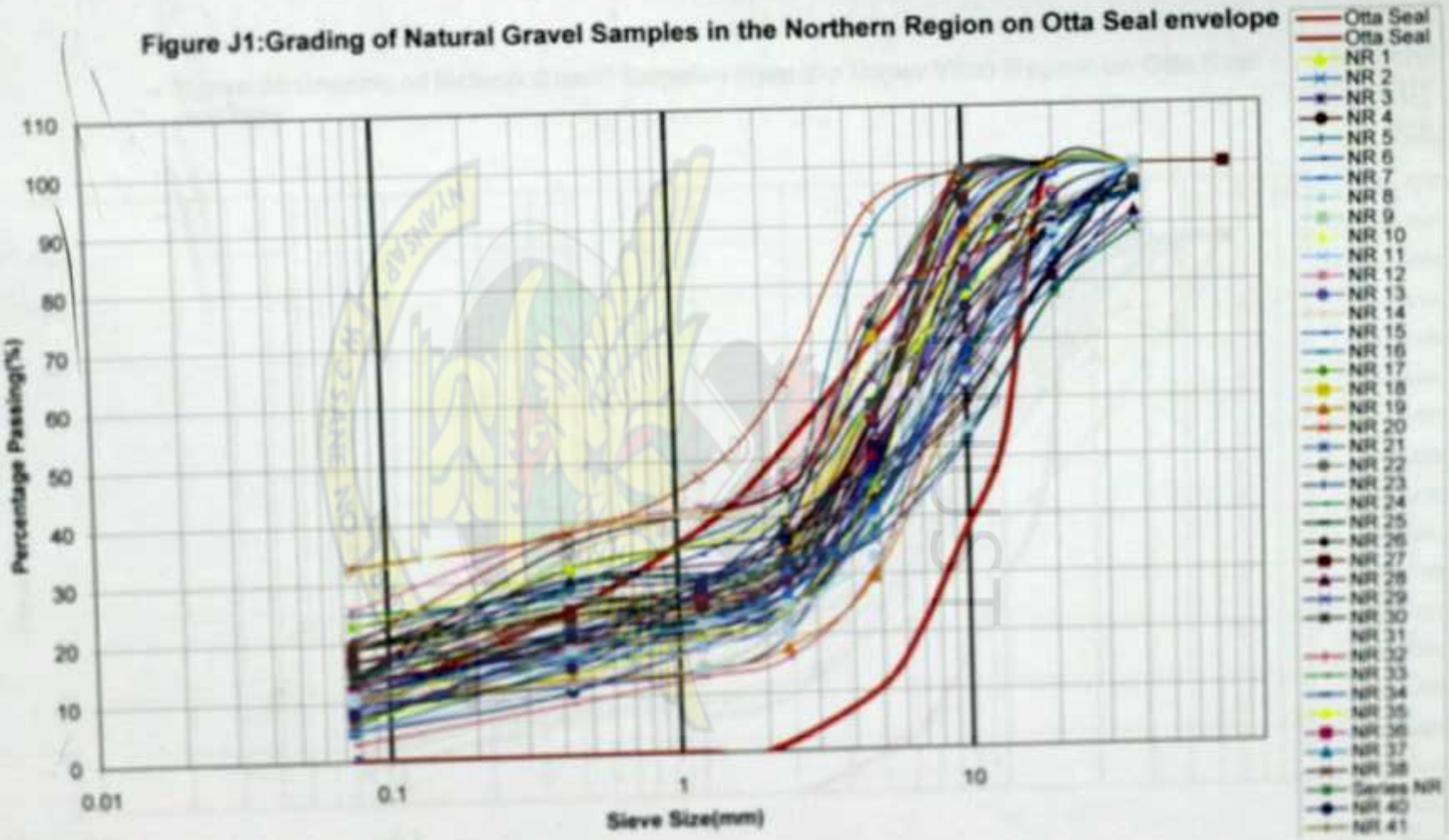

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Figure J2:Grading of Natural Gravel Samples from the Upper West Region on Otta Seal envelope

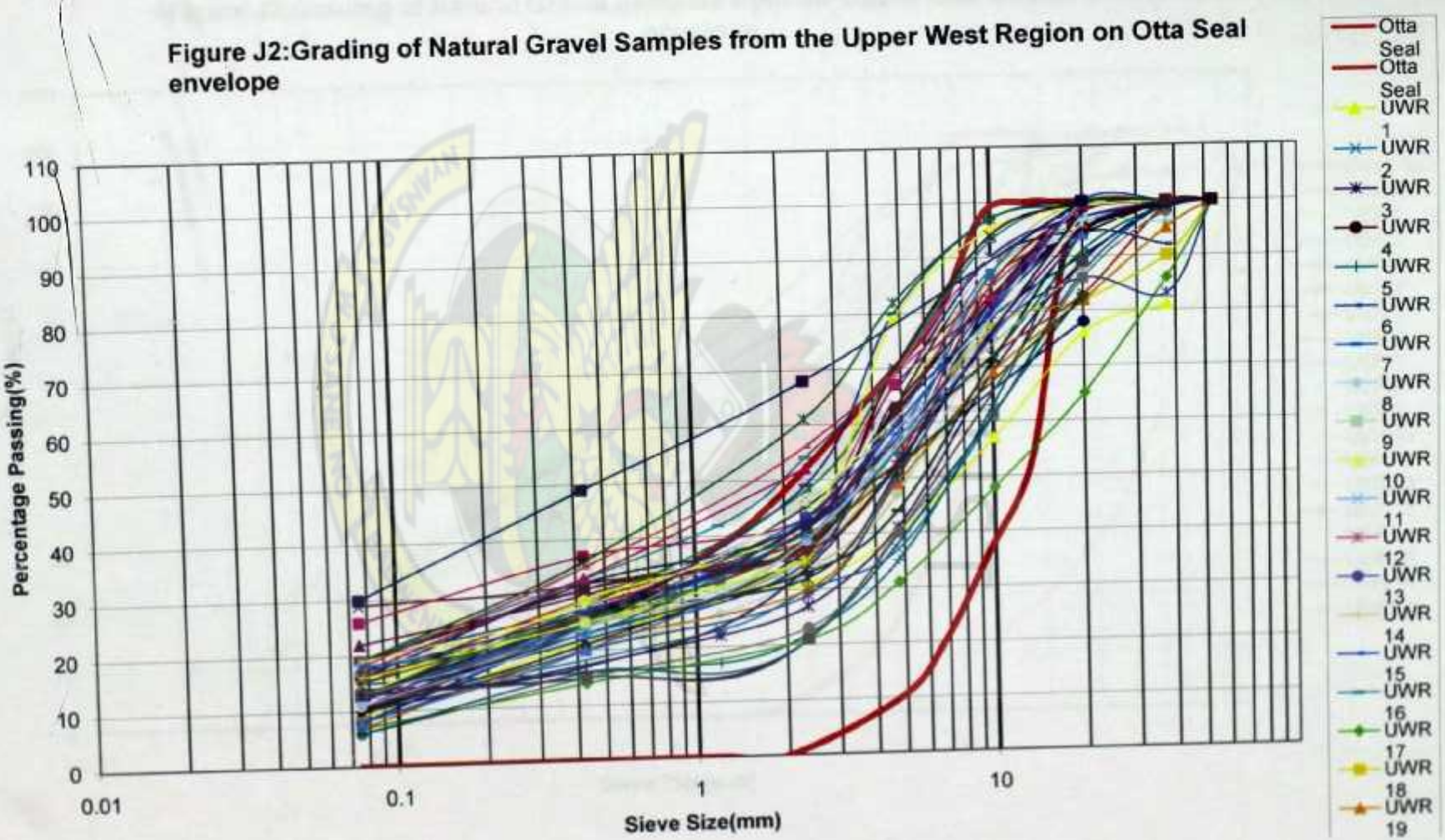

Figure J3:Grading of Natural Gravel Samples from the Upper East Region on Otta seal envelope

Figure J4:Grading of Natural Gravel Samples from Ashanti Region on Otta Seal envelope

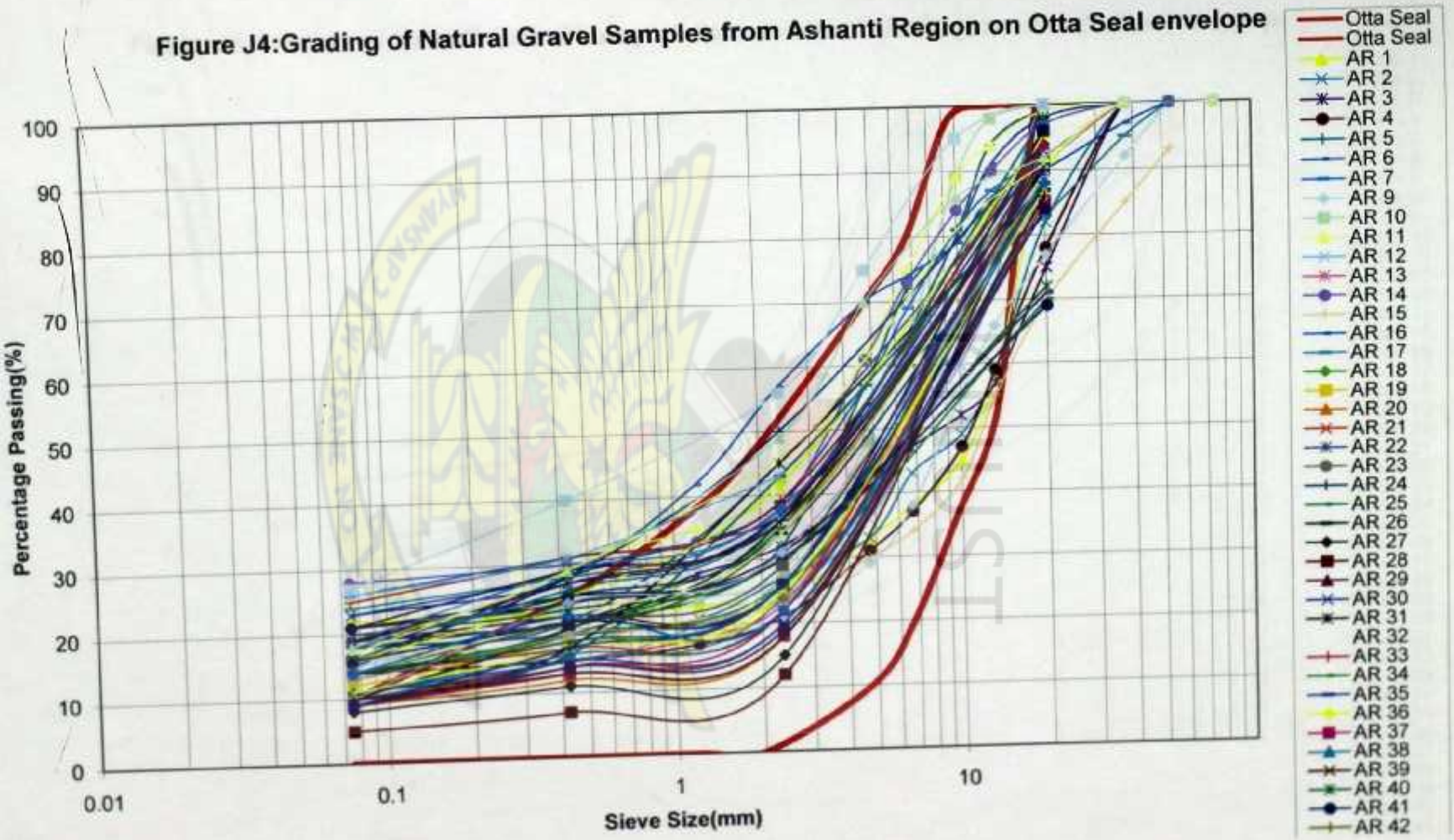

Figure J5:Grading of Natural Gravel Samples form the Western Region on Otta Seal envelop

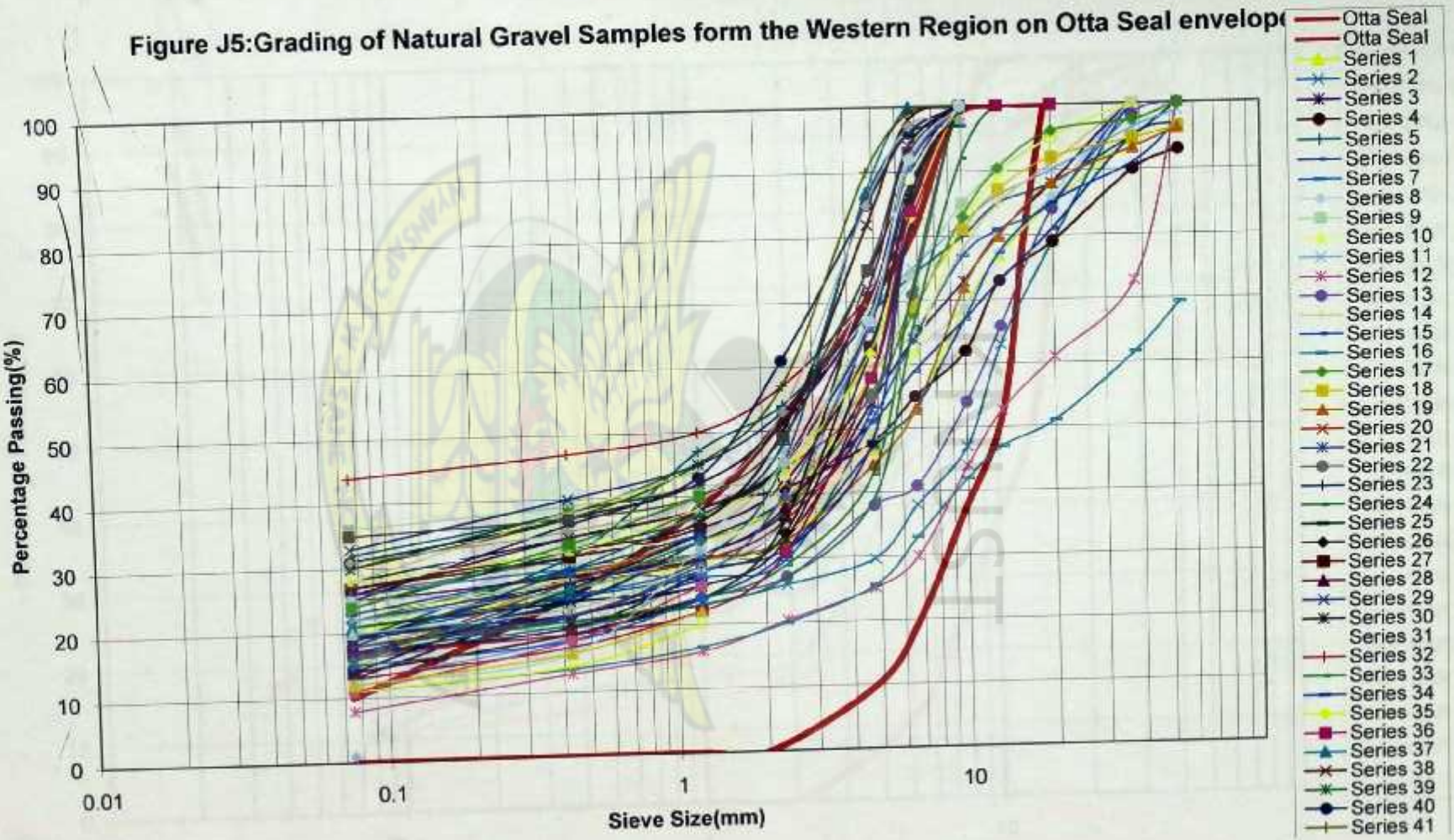

Figure J6:Grading of Natural Samples from the Brong Ahafo Region on Otta Seal envelope

Figure J7:Grading of Natural Gravel Samples in the Eastern Region on Otta Seal envelope

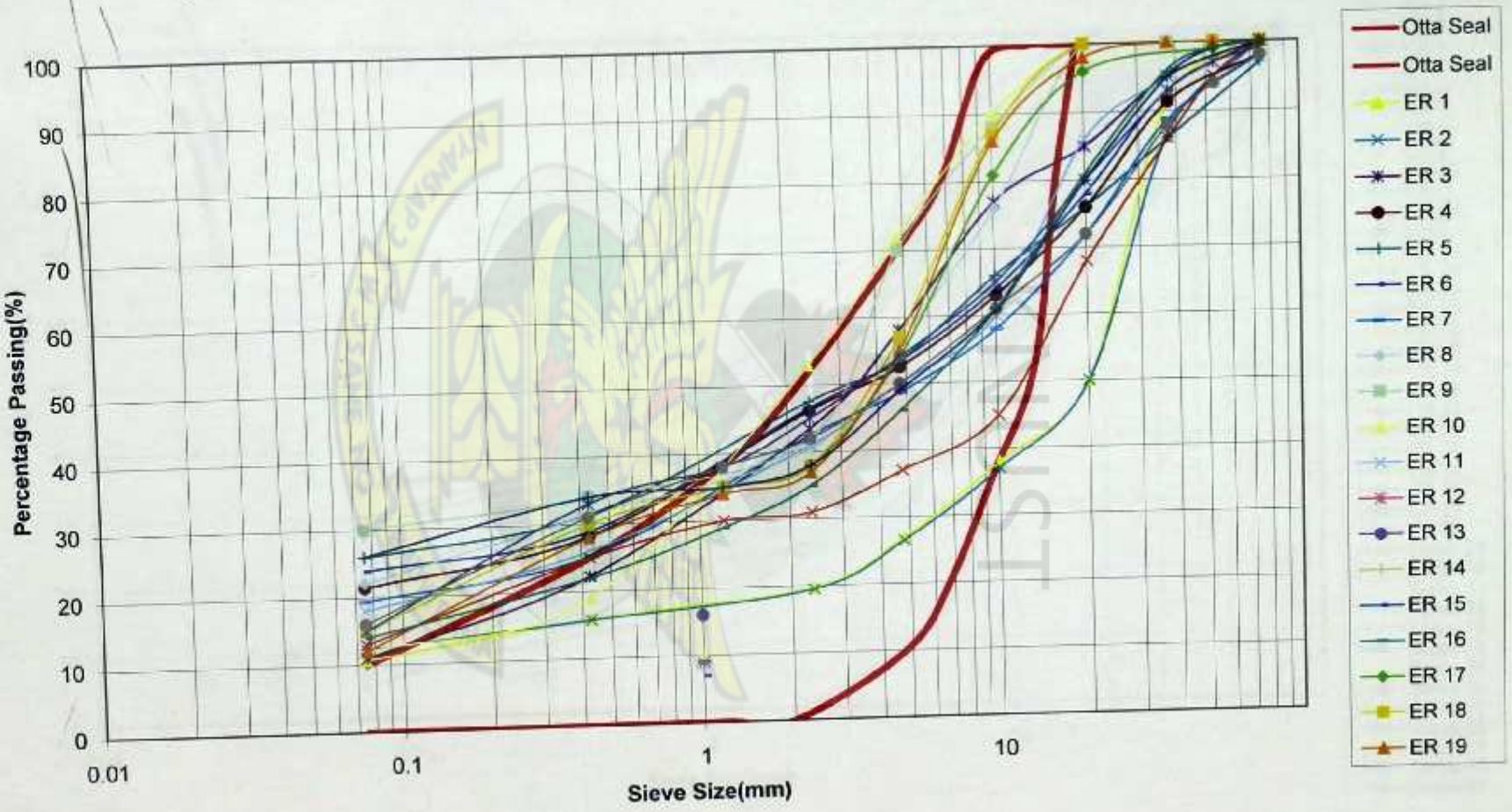

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Figure J8:Grading of Natural Samples from the Central Region Superimposed on Otta Seal envelop

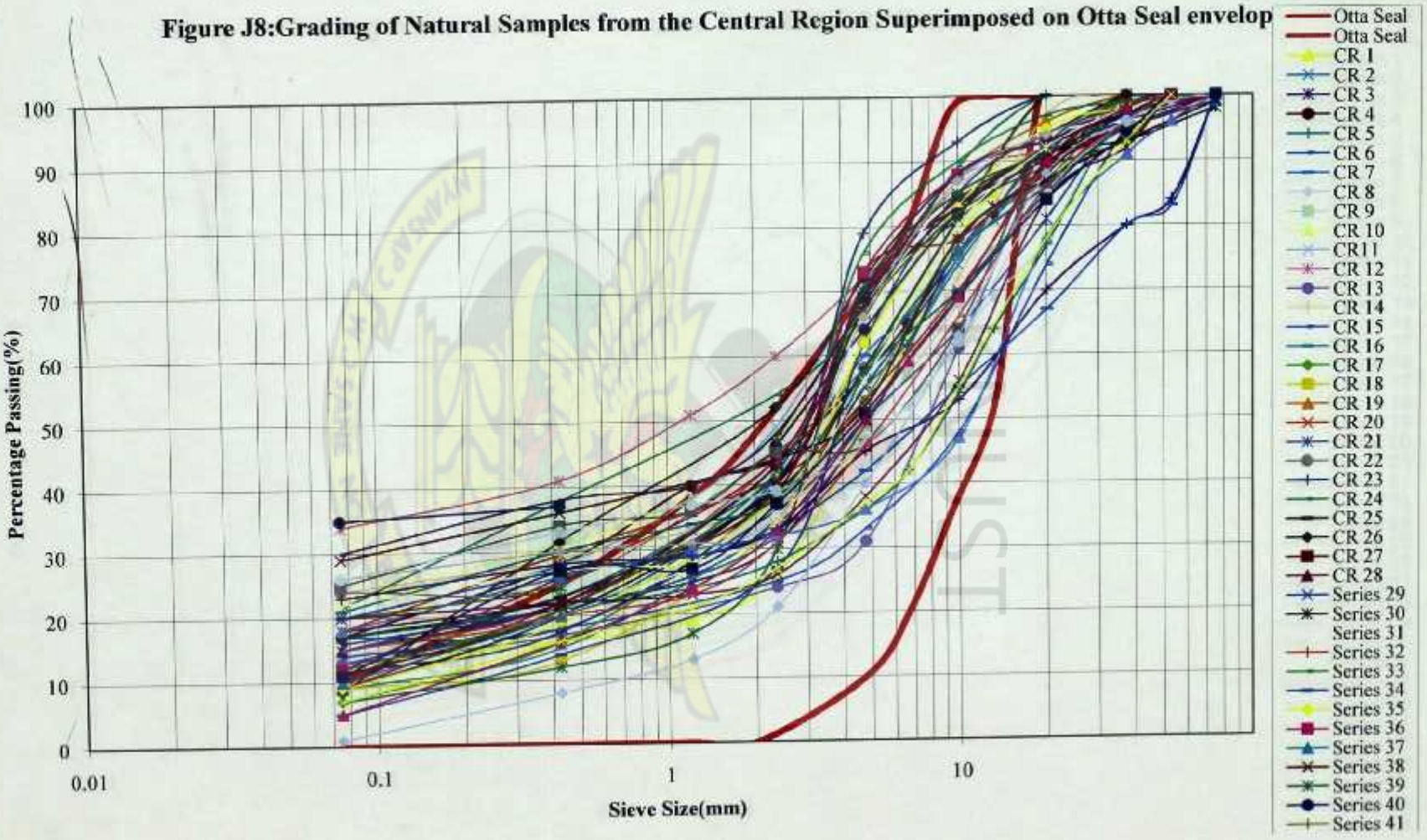

Figure J9:Grading of Natural Gravel samples from the Volta Region on Otta Seal envelope

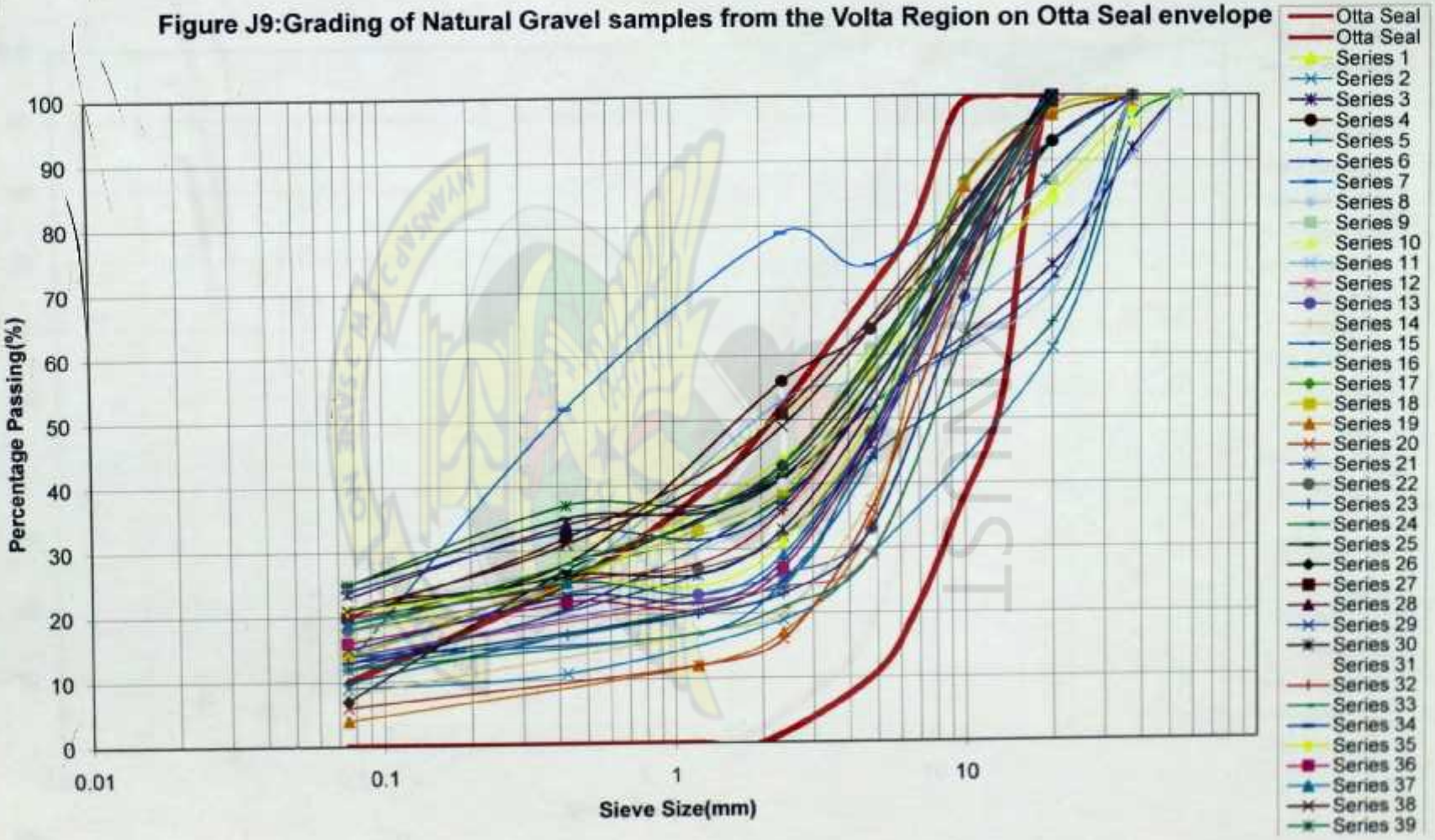

Figure J10:Grading of Natural Gravel Samples from the Greater Accra Region on Otta Seal envelope