STUDY ON UTILIZATION OF BUILDING DEBRIS IN ROAD CONSTRUCTION IN NORTHERN PROVINCE OF SRI LANKA

Pirashanthy Shankar
(118818M)

Degree of Master of Engineering

Department of Civil Engineering

University of Moratuwa
Sri Lanka

March 2016

STUDY ON UTILIZATION OF BUILDING DEBRIS IN ROAD CONSTRUCTION IN NORTHERN PROVINCE OF SRI LANKA

Pirashanthy Shankar

(118818M)

Thesis submitted to University of Moratuwa in partial fulfillment of the requirements for the Degree of Master of Engineering in Foundation Engineering and Earth Retaining Systems

Department of Civil Engineering

University of Moratuwa

Sri Lanka

March 2016

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any University or other institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant the University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:............................ Date:..01/04/2016

The above candidate has carried out research for the Master Dissertation under my supervision.

Signature of the ~~Co~~ -Supervisor :. UOM Verified Signature Date:..01/04/2016

Dr.U.P.Nawagamuwa

B.Sc.Eng (Moratuwa), M.Eng (AIT), Ph.D.(Tokyo)

Senior Lecturer,

Department of Civil Engineering,

University of Moratuwa,

Moratuwa,

Sri Lanka.

ABSTRACT

Due to rapid development and population growth, construction industry has emerged with few new problems. The major problem faced by the industry is the scarcity of construction material and disposal of construction waste because of high disposal cost and inadequate land fill area.

Northern region of Sri Lanka is undergoing a massive infrastructure development within a shorter period especially in the road sector development. Roads are major consumers of aggregate and soil and the influence of aggregate cost is more in total construction cost of the roads.

The aggregates for these road construction projects are transported from Medawachchiya due to scarcity of local material and the approximated transport distance from Medawachchiya is more than 150 km. Hence, transport cost is approximately 70% of the project cost. In order to curtail the cost of construction of roads and reduce the industrial waste disposal, the possibility of using building waste as road construction material has been studied.

Building debris such as concrete, random rubble masonry, concrete block and plaster were selected for this research. Experimental studies were carried out to determine the engineering properties of the recycled construction material and compared with conventional road construction material. Aggregate Impact Value Test, Aggregate Crushing Value Test, Los Angeles Abrasion Test and California Bearing Ratio Test were carried on selected building debris to find out the suitability for road base construction. Crushed samples of selected debris were tested to determine the suitability for replacement of soil in road construction. It has been observed that the Random Rubble Masonry debris can be directly used for road base construction however, crushed debris of block masonry, plaster and concrete can replace the soil for construction of sub base, shoulder, embankment and for surface of ‘D’ & ‘E’ class roads after adding suitable percentage of plastic clay.

ACKNOWLEDGEMENTS

I am most grateful to Dr.U.P.Nawagamuwa for his dedication and commitment throughout the research work as my supervisor. He gave me good guidance and constructive criticism to complete my project successfully. I am also grateful to the course coordinator Dr.U.P.Nawagamuwa and the research coordinator Dr. Nalin De Silva.

I wish to thank the Vice Chancellor, Dean, Faculty of Engineering and the Head, Department of Civil Engineering of University of Moratuwa for allowing me to make use of the facilities available at the University.

I also wish to thank all the lecturers of the post graduate course on Foundation Engineering & Earth Retaining System for their valuable efforts in the lecture series and for giving guidance and encouragement to get success in my professional career.

I am also thankful to the Director General and Director Training of Road Development Authority for sponsoring me for this postgraduate study. I am particularly indebted to thank to my superiors, Director and the Deputy Director for nominating me for the course and providing office facilities to complete this study. Further, I wish to thank staff of Road Development Authority, Northern Province for supporting me in several ways to complete my Research. My sincere thanks ought to Director Research & Development of RDA and other technical staffs of Research and Development branch for helping me to carry out the tests in the laboratory.

Finally I would like to thank my family members for their kind support extended to me.

Pirashanthy Shankar,

Road Development Authority

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AIV	-	Aggregate Impact Value
ACV	-	Aggregate Crushing Value
LAAV	-	Los Angeles Abrasive Value
CBR	-	California Bearng Ratio
LL	-	Liquid Limit
PL	-	Plastic Limit
PI	-	Plastic Index
MDD	-	Maximum Dry Density
OMC	-	Optimum Moisture Content
SSCM	-	Standard Specification of Construction & Maintenance of Roads & Bridges
BS	-	British Standards
ASTM	-	American Standards for Testing and Materials

CHAPTER 1

1.0 INTRODUCTION

1.1 GENERAL INTRODUCTION

Due to rapid development of infrastructure and population in Sri Lanka, construction industry has become very dynamic. The problems faced by the Government of Sri Lanka are scarcity of construction material and disposal of construction and demolished waste because of unavailability land fill area which could be used as dumping sites.

After the three decades of war, Northern region of Sri Lanka is undergoing massive infrastructure development within a shorter period especially in the road sector development.

Figure 1.1 Road Sector Development in the Northern Province of Sri Lanka

Recently, the Northern region encountered problems in finding road construction material for their road projects. Roads are major consumers of aggregate and soil. The aggregates for these road constructions are transported from Medawachchiya, the approximated transport distance from Medawachchiya is more than 150 km. Hence, transport cost is approximately 70% of the project cost.

Eg. Cost analysis for Construction of Aggregate Base Course based on Highway Schedule Rate 2014 (HSR)

Construction of Aggregate Base Course (without transport) = Rs. 2,105.80

Transport of Aggregate from Medawachchiya to Jaffna = 31.65 Cum/Km x 150 Km

= Rs. 4,747.50

Hence, transport cost is 70% of construction cost.

Figure 1.2 Aggregate Usage in Road Construction

There are several major road construction projects carried out by the Government of Sri Lanka in Northern Province under GOSL and foreign funding.

In addition to that, disposal of huge quantity of building debris is also a problem to the Government because of limited landfill area and huge cost of transportation. Major parts of the land in Northern region are paddy field, cultivation land and minor tanks and most of the people do farming. So, disposing industrial waste in these lands cause flooding, environmental problem and affect their livelihood activities. Hence, it is the best solution to reuse the construction waste and building debris for construction projects.

Figure 1.3 Building Debris

This research consists of testing of selected building debris to find out the suitability for road construction. The conventional aggregate testing adopted in Highway sector for road base construction are Aggregate Impact Value Test, Aggregate Crushing Value Test, Los Angels Abrasion Value Test, Specific gravity and water absorption test and aggregate grading and California Bearing Ratio test.

The land use of Northern Region mainly consists of residential and agricultural lands including paddy fields and mixed cultivation. The majority of roads are ‘C’, ‘D’ & ‘E’ class roads (ie. earth roads). The major construction material used in ‘C’, ‘D’ & ‘E’ class roads is soil. In addition, soil is used for construction of sub base, shoulder and embankment of all categories of roads. Hence, crushed building debris is tested to find out the suitability for replacing soil in road construction. The conventional soil testing adopted in Highway sector are California Bearing Ratio test, Compaction Test & Consistency Test.

In this research samples of plaster, concrete, block masonry and random rubble masonry sample were collected from Jaffna District, Northern Province of Sri Lanka and standard aggregates tests were carried out for each sample separately according to the BS 812 and soil tests were carried out for crushed samples separately. The results obtained from the tests were analyzed and compared with the ICTAD publication No. SCA/5, Second Edition, June 2009; ‘Standard

Specification for Construction and Maintenance of Roads and bridges (SSCM)' issued under the authority of the Director General of the Road Development Authority. Conclusions and recommendations are laid down based on these compared results.

1.2 PROBLEM STATEMENT

1. Scarcity of road construction material in Northern Province of Sri Lanka.
2. Problems due to disposal of Abandoned building debris considering the cost of transportation and limited landfill area
3. Are there any possibilities to reuse of building debris for road construction in Northern Province of Sri Lanka?

1.3 OBJECTIVES

The main objectives of the research presented are as follows;

1. To find out the suitability of building debris experimentally in road construction project in Northern region of Sri Lanka
2. To make recommendation on how to minimize building debris disposal problem in Northern region of Sri Lanka.

1.4 METHODOLOGY

The objectives were achieved using the following methodology.

- Identification & collection of different types of building debris in Northern Region.
- Experimental testing of properties of various kind of building debris.
- Comparison of results with conventional material properties.
- Conclusions & recommendations

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 INRODUCTION

Demolition debris consists of waste that is generated during renovation and demolition of building, roads and bridges. Demolition of building debris often contains bulky heavy material that includes:

- Concrete, wood
- Metals, bricks, glass and plastics
- Salvaged building components such as doors, windows and plumbing fixtures.

Significant volumes of demolition debris are generated in Sri Lanka and ends up in municipal solid waste landfills or incinerators. Government of Sri Lanka (GOSL) is facing difficulties in finding solid waste landfills and costly disposal of demolition waste especially in urban area. Hence, GOSL is continuing to work in order to divert this waste away from land disposal by promoting the reuse and recycling of demolition debris and reducing its generation through green building. Reducing demolition debris conserve landfill space, reduces the environmental impact of producing new materials and can reduce overall project expenses through avoided purchase and transportation costs. Some states enforce local regulations & policies to limit disposal of demolition debris and promoting to reduce, reuse & recycle waste (United States Environmental Protection Agency). Reducing and recycling C&D materials conserves landfill space, reduces the environmental impact of producing new materials, creates jobs, and can reduce overall building project expenses through avoided purchase/disposal costs (U.S.Environmental Protection Agency).

The road sector is booming due to urbanization and infrastructure development in Northern Region of Sri Lanka leads to seek huge quantity of construction material. Nowadays, old traditional buildings are demolished and built new multistorey buildings for upgrading living standard of people according to the current trend and availability of limited lands.

Demolition debris is quickly gaining attention in Northern region of Sri Lanka as people continue to resettle; large scale infrastructure developments continue to spring up throughout the Northern Province after the 30 years of war. The development and redevelopment associated with this growth is causing a tremendous increase in the demolition waste. The most common types of demolition waste exist in the area are concrete, plaster, wood, cement block & rubble masonry. The better solution to reduce the environmental issue is to recycle these wastes.

Roads are major consumers of aggregate and soil and the influence of aggregate cost is more in total construction cost of the roads. Crushed concrete and brick are often used as base fill in the construction of roads. This is an economical construction method and represents a large potential market but purity (i.e. presence of wood, dirt, other contamination) of the material may also be an issue. Crushed concrete and brick may also be used as primary road surface material on unpaved roads in rural areas. The use of crushed concrete for driveways is also practiced (Braen, 2013). The use of recycled materials can help reduce the costs and environmental impact of road construction.

Crushed concrete that has been well screened of fine particles provides similar drainage characteristics as new rock or gravel. It is, therefore, often used for drainage applications in construction (dep.state.fl.us, 2000).

Recycled concrete aggregates contain not only the original aggregates, but also hydrated cement paste. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity leads to a higher absorption (PCA, America's Cement Manufacturers).

Recycling of demolition waste provides sustainability in several different ways. The simple act of recycling the concrete reduces the amount of material that must be land filled. As space for landfills becomes premium, this not only helps reduce the need for landfills, but also reduces the economic impact of the project. Moreover, using recycled demolition wastes reduces the need for virgin construction material. This in turn reduces the environmental impact of the virgin construction material extraction process. By removing both the waste disposal and new material production needs, transportation requirements for the project are significantly reduced.

Aggregates generated from quarries, produce number of environmental problems like noise and dust pollutions. Generally, quarries are located on the outskirts of city limits. But, as cities grow, these quarries have to be relocated further away from urban centers. The cost involved in transporting the aggregate increases tremendously due to this increase in distance between construction site and aggregate production. The problem arises while disposing the demolished debris once its design life is over. The availability of landfill sites for disposal of waste has been drastically decreased due to strong environmental lobby. With the limited supply of landfill sites and great demand for waste disposal, the cost of dumping of waste has been increased in recent times. Hence, it is vital to study the use of recycled aggregate from building debris as base and sub base course to reduce the material transport cost and disposal cost.

Soils & aggregate are the basic materials in road construction. However their engineering properties and behavior will vary considerably. As such the testing of these materials is very essential to ensure the quality and durability of the road constructed.

Natural rock aggregate are the basic materials used in highway pavement construction in Sri Lanka. In Northern Province of Sri Lanka, there are very less good quality of rock & soil available for road construction. Aggregates must support the stresses occurring within the pavement in addition the aggregate must resist wear due to abrasion by traffic as well as the weathering effects of the natural elements. The physical and mechanical properties which govern the suitability of rock aggregate for road construction purpose depend on rock group and quarry. The desirable properties of aggregate relevant to road construction are listed below (Director(R&D), 2006),

i. Resistance to impact and crushing under traffic loads and construction equipment (strength).
ii. Resistance to abrasion and polishing under the action of tyres and vehicles (Hardness).
iii. Resistance to weathering (Durability).
iv. Angular shape and rough surface texture to provide good interlock.
v. Free of flaky and elongated particles.
vi. Good adhesion to bituminous binders.

2.2 LABORATORY TESTS TO DETERMINE PROPERTIES OF MATERIAL IN ROAD CONSTRUCTION

2.2.1 TESTS ON AGGREGATES

2.2.1.1 Aggregate Impact value (AIV)

The aggregate Impact Value gives a relative measure of the resistance of an aggregate to sudden shock of impact. The test is carried out according to BS 812, part 112. Thus it will be seen that higher the aggregate impact value weaker is the aggregate. Generally, aggregate whose aggregate impact value is greater than 30% is not used in road construction.

2.2.1.2 Aggregate Crushing Value (ACV)

The aggregate crushing value is a measure of the resistance of an aggregate to crushing under a gradually applied compressive load. As per BS 812 part 110, the test is carried out to determine ACV value. The aggregate with a low aggregate crushing value is stronger than an aggregate which has a high value. Generally, aggregate whose aggregate crushing value is greater than 35% is not used in road base construction.

2.2.1.3 Los Angeles Abrasion Value Test (LAAV)

This test attempts to measure the deterioration of aggregate particles subjected to attrition. ASTM method test is done to determine LAAV value (ASTM C131). A low value of LAAV reflects and aggregate which is more resistant to abrasion. The aggregate with LAAV greater than 40 are too soft for road base construction.

2.2.1.4 Flakiness Index

The flakiness index of an aggregate is the percentage by weight of particles whose least thickness is less than 3/5ths of their mean dimension. In order to ensure good interlock and prevent excessive crushing of the aggregate it is important that the flakiness index of the material should be low. Aggregate whose flakiness index is greater than 35 is not recommended for road base construction. The test is carried out according to BS 812 part 105.1.

2.2.1.5 Water absorption

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests. In road construction, water absorption of the aggregate is limited to 2%. As per ASTM, C127, the test is carried out.

2.2.2 TESTS ON SOIL

In road Construction, soil is used for construction of sub base, shoulder, embankment and surface of ‘D’ & ‘E’ class roads. The desirable properties of soil relevant to road construction are determined by carrying out following tests based on BS 1377-1990,

i. Calfornia Bearing Ratio Test.
ii. Consistency Test
iii. Compaction Test.

2.2.2.1 California Bearing Ratio (CBR)

The California bearing ratio test, usually abbreviated as CBR test, is a special purpose penetration test, developed by the California State Highway Department for the evaluation of sub grade or road pavement strengths for roads. The load required to cause a plunger of standard size to penetrate a specimen of soil at a standard rate of penetration is measured. The CBR value is the result of an empirical test on soil, which in conjunction with design curves can be used to determine the required thickness of a road pavement. For the purpose of pavement design, the test may be carried out on remolded samples, representing material compacted on the site or on undisturbed samples obtained from the sub base or on samples from earthworks after compaction.

2.2.2.2 Liquid Limit

The strength and behavior of fine grained soils varies considerably with the water content of the soil. As the water content increases, the soil passes from plastic state into a liquid state. The liquid limit defines the water content at which the transition occurs for a particular soil. The desirable liquid limit value of suitable material for different type of usages in road construction is defined in SSCM for Roads & Bridges as follows,

Table No. 2.1 – Desired Liquid Limit Value of Road Construction Material

Description	Desirable Liquid Limit Value / (%)
Sub base	< 40
Embankment	< 50
Shoulder	< 55
Soil surface	< 50

2.2.2.3 Plastic Limit

Plastic limit of the soil is the lower moisture content at which the soil is plastic.

2.2.2.4 Plasticity Index

The plasticity Index is defined as range of the water content within which soil achieves its plastic state. This is equal to the difference between liquid limit and plastic limit. The desirable Plasticity Index value for different type of usages in road construction defined in sub section 1708 of SSCM for Roads & Bridges as follows,

Table No. 2.2 – Desired Plasticity Index Value of Road Construction Material

Description	Desirable Plastic Limit Value / (%)
Sub base	< 15
Embankment	< 25
Shoulder	6 - 25
Soil surface	6 - 25

2.2.2.5 Modified Compaction Test

The object of the laboratory compaction test is to obtain the relationship between dry density and moisture content for a controlled degree of compaction, from which the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for that amount of compaction can be derived. The point at which the highest value of dry density obtained for the given amount of compaction is the Optimum Moisture Content and the corresponding dry density is the Maximum Dry Density. In SSCM for roads and bridges, the desirable values of Modified Maximum Dry Density for different kinds of usages in road construction have been given as follows,

Table No. 2.3 – Desired Maximum Dry Density Value of Road Construction Material

Description	Desirable MDD (modified) / (kg/m^3)
Sub base	> 1750
Embankment	> 1600
Shoulder	>1600
Soil surface	>1650

2.3 DESIRED MATERIAL PROPERTIES IN ROAD CONSTRUCTION

2.3.1 AGGREGATE

2.3.1.1 Base Construction

Base is constructed on a prepared sub base or existing paved surface. The aggregate which is derived from a parent rock that is hard, sound, durable and un-weathered and free of dust, organic matter, clay and silt or any other deleterious matter is used for construction. According to SSCM for Roads & Bridges, the road base aggregate shall have following properties,

Table 2.4 - Desired Properties of Road Base Material (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Property	**Value**
AIV	Not to exceed 30%
Flakiness Index	Not to exceed 35%
LAAV	Not to exceed 40%
PI	Not to exceed 6%
4 – day soaked CBR	Not less than 80%
Water absorption	Not to exceed 2%

The road base material shall be graded to nominal size of 37.5 mm or 28 mm or 20 mm conforming to the grading requirements tabulated below.

Table 2.5 – Grading of Material for Road Base (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Sieve Size		**% by weight passing sieve**		
mm	**µm**	**37.5mm**	**28 mm**	**20 mm**
50		100		
37.5		95 – 100	100	
28		-	-	100
20		60 – 80	70 – 85	90 - 100
10		40 – 60	50 – 65	60 - 75
5		25 – 40	35 – 55	40 - 60
2.36		15 – 30	25 – 40	30 - 45
	425	7 – 19	12 – 24	13 - 27
	75	5 – 12	5 – 12	5 - 12

2.3.2 SOIL

2.3.2.1 Properties of soil topping for earth roads

According to the Standard Specification for Construction and Maintenance of Bridges and Roads (June 2009), gravelly and sandy soils with a little clay, whose maximum dry density when compacted under standard condition of compaction is not less than 1650 kg/m^3 and whose liquid limit (LL) and plasticity index (PI) are 40 and between 4 & 25 respectively for wet and intermediate zones and LL and PI are 55 and between 6 & 25 respectively for dry zone may be used as soil topping for earth roads.

2.3.2.2 Properties of intermediate layer for Gravel roads

As per the Standard Specification for Construction and Maintenance of Bridges and Roads (June 2009), gravelly and sandy soils whose CBR under 4 days soaked conditions when compacting 100% maximum dry density under standard conditions of compaction, is not less than 8 with liquid limit (LL) and plasticity index (PI) are 40 and between 4 & 15 respectively for wet and intermediate zones and LL and PI are 50 and between 6 & 25 respectively for dry zone may be used.

2.3.2.3 Properties of Gravel surfacing

According to the Standard Specification for Construction and Maintenance of Bridges and Roads (June 2009), well graded gravelly soil with a little clay and plasticity characteristics and CBR value not less than 15% at the density and moisture condition can be used for surfacing of gravel roads.

2.3.2.4 Properties of sub base material

As per the Standard Specification for Construction and Maintenance of Bridges and Roads (June 2009), two types of soil sub bases, type I and type II are specified for use. The soil sub base type I should have a minimum CBR 30% at the designated conditions of moisture content and density and is to be used for the top layer of the sub base. For the lower layer of the soil sub base type II may be used should have a minimum CBR 15% at the designated conditions of moisture content and density. For both types of sub bases, the liquid limit and plasticity index should not exceed 40 and 15 respectively.

Table 2.6 - Desired Properties of Upper Sub – base material (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Property	Value
Liquid Limit (LL)	Not to exceed 40%
Plastic Index (PI)	Not to exceed 15%
Maximum Dry Density (Modified)	Not less than 1750 kg/m^3
4 – day soaked CBR at 98% MDD	Not less than 30%

Table 2.7 - Desired Properties of Lower Sub – base material (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Property	Value
Liquid Limit (LL)	Not to exceed 40%
Plastic Index (PI)	Not to exceed 15%
Maximum Dry Density (Modified)	Not less than 1650 kg/m^3
4 – day soaked CBR at 95% MDD	Not less than 15%

Table 2.8 Grading of Sub base material (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Sieve Size		**% by weight passing sieve**
mm	**µm**	
50		100
37.5		80 – 100
20		60 – 100
5		30 – 100
1.18		17 – 75
	300	9 – 50
	75	5 - 25

2.3.2.5 Road Shoulders

The road shoulders are an important part of the road pavement structure. The road shoulders provide lateral support to the pavement structure and should be able to carry occasional vehicles. According to the Standard Specification for Construction and Maintenance of Bridges and Roads (June 2009), the material used for shoulders should be as cohesive as possible without being too weak when wet. Road shoulders are generally constructed using soil with a minimum CBR value of 15% at the designated conditions of moisture content and density.

Table 2.9 - Desired Properties of Road Shoulder Material (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Climatic Zone	**LL**	**PI**	**CBR (%)**
Wet Zone	Not to exceed 50%	4 - 25	> 15
Dry Zone	Not to exceed 55%	6 - 25	>15

2.3.2.6 Road Embankment

Embankment material shall not include highly plastic clay, silt, peat or other organic material or any contamination such as vegetable and other deleterious matter. As per the Standard Specification for Construction and Maintenance of Bridges and Roads (June 2009), the material used for the top 500 mm of embankment shall conform to the requirements of type I material, and the material for lower layers of embankment shall conform to the requirements of type II material as given below,

Table 2.10 - Desired Properties of Road Embankment Material (Ref. : SSCM for Roads & Bridges second edition, June 2009)

Property	**Embankment Type I**	**Embankment Type II**
Liquid Limit (LL)	Not to exceed 50%	Not to exceed 55%
Plastic Index (PI)	Not to exceed 25%	Not to exceed 25%
Maximum Dry Density (Modified)	Not less than 1600 kg/m^3	Not less than 1500 kg/m^3
4 – day soaked CBR at 95% MDD	Not less than 7%	Not less than 5%

CHAPTER 6
REFERENCES

1. American Society for Testing and Materials

2. British Standards 812

3. British Standards 1377

4. Standard Specification for Construction and Maintenance of Roads and Bridges, ICTAD SCA 5 (June 2009).

5. Braen, D. (2013, 9 6). *Braen Stone*. Retrieved 9 25, 2013, from Buying Crushed Concrete for Driveways & Patios: http://www.braenstone.com/2013/09/buy-crushed-concrete-driway-patios/

6. *dep.state.fl.us*. (2000). Retrieved 7 2, 2013, from C&D Debris Recycling Study: Final Report - Florida: http://www.dep.state.fl.us/waste/quick_topics/publications/shw/re

7. Director(R&D). (2006, 2 16). Testing of Road Construction Materials. Colombo, Western, Sri Lanka: Road Development Authority.

8. *PCA, America's Cement Manufacturers*. (n.d.). Retrieved 7 2, 2013, from Recycled Aggregates: http://www.cement.org/for concrete books learning/concrete-design-production/recycled-aggregates

9. *U.S.Environmental Protection Agency*. (n.d.). Retrieved 7 2, 2013, from Wastes - Resource Conservation - Reduce, Reuse, Recycle - Construction & Demolition Materials: http://www.epa.gov/wastes/conserve/imr/cdm/

10. *United States Environmental Protection Agency*. (n.d.). Retrieved 7 2, 2013, from Construction and Demolition (C&D) Debris: http://www.epa.gov/region1/solidwaste/cnd/

CHAPTER 3

3.0 TESTING AND CALCULATION

3.0 INTRODUCTION

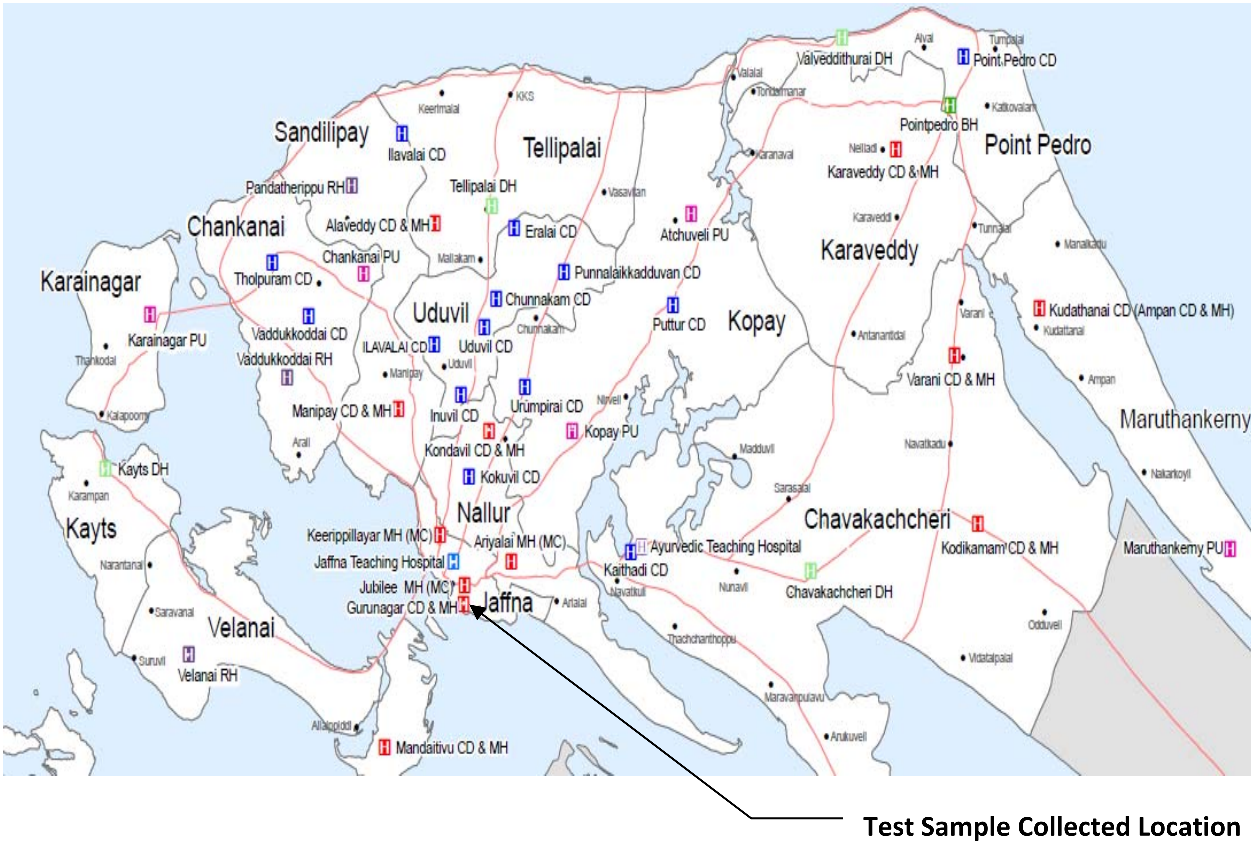


Figure 3.1 – Jaffna Map

A ground stratum of Jaffna Peninsula consists of lime stone. In Northern Province of Sri Lanka, Jaffna lime stone is used as aggregate in construction work considering cost of transportation of granite aggregates from Medawachchiya. Due to the continuous excavation of lime stone, lime stone resource is diminishing gradually and intrusion of sea water towards the lands has caused an increase in salinity level of the underground water. Hence, excavation of lime stones is now reduced and GOSL wants to seek an alternative cost effective material for construction works.

Due to three decades war, there are abundant building debris and needed to dispose without environmental pollution. Since, the cost of disposal is high, it is useful to recycle these debris for construction work.

The major building debris found in this region are reinforced concrete, concrete blocks, plaster and RR masonry. The following aggregate tests were carried out for the raw building debris of reinforced concrete, concrete block, plaster and RR masonry separately to find out the suitability for road base construction.

- Aggregate Impact Value
- Aggregate Crushing Value
- LAAV

Each building debris of reinforced concrete, concrete block, cement plaster and RR masonry were crushed separately and tested to find out suitability for construction of ‘C’ & ‘D’ class roads, sub base, shoulder and embankment. Since crushed debris do not contain any plasticity and required percentage of fine particles, compaction couldn’t be achieved. In order to improve compaction and CBR value, clay, gravely soil and crushed debris was mixed with at the ratio of 1: 2:3 (Clay: gravely soil: crushed debris) depending on the regional experience. The following fine material tests were carried out,

- California Bearing Ratio
- Compaction test
- Soil Consistency Test

3.1 AGGREGATE IMPACT VALUE TEST (AIV)

3.1.1 Observation

Aggregate Impact Value test for different type of building debris were conducted based on BS 812, part 112.

Table 3.1 Aggregate Impact Value Test of Concrete debris

Test No.	1	2
Weight of sample (g)	248.6	248.2
Weight of sample passing 2.36 mm sieve after test (g)	86.3	89.5
Weight of sample retained on 2.36 mm sieve after test (g)	161.7	158.3

Observations of Aggregate Impact Value Test of RR Masonry, Concrete block and cement plaster debris are tabulated in Appendix 1.

3.1.2 Specimen Calculation

From table 3.1, 2nd set of readings,

Weight of sample in standard measure = 248.2 g

Weight of sample passing 2.36 mm sieve after test = 89.5 g

Weight of sample retained on 2.36 mm sieve after test = 158.3 g

Hence, Aggregate Impact Value of concrete debris = 36.0 %

Similarly,

From 1st set of readings, Aggregate Impact Value = 34.7 %

Hence, Average Aggregate Impact Value of concrete debris = 35 %

3.1.3 Results

Similarly, calculation was done for RR Masonry debris, concrete block debris and cement plaster separately and results are tabulated below,

Table 3.2 Results of Aggregate Impact Value Test of different type of debris

Test No.	1	2	Average
Concrete debris	36.0 %	34.7 %	35 %
RR Masonry debris	24.6 %	25.4 %	25 %
Concrete block debris	36.8 %	37.2 %	37 %
Cement plaster debris	Result was unable to obtain		

These results are shown graphically in figure 3.2.

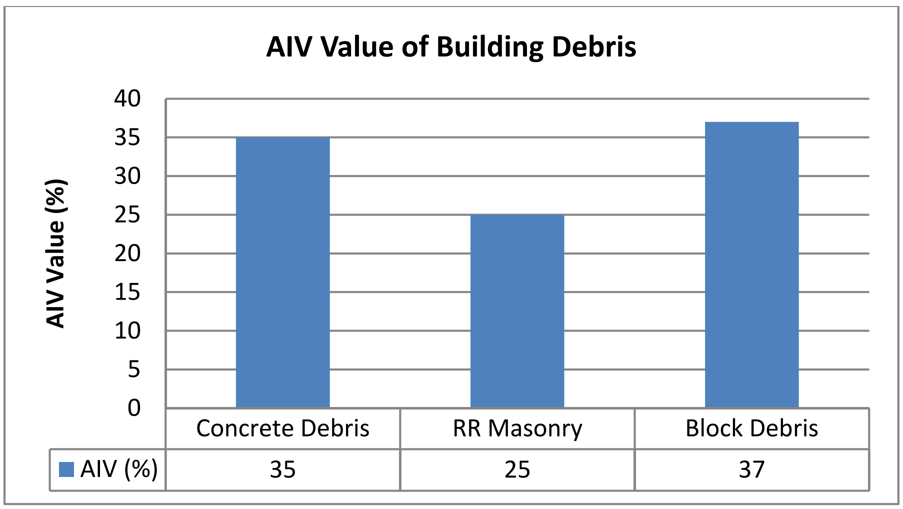


Figure 3.2 Aggregate Impact Value of different type of debris

3.2 AGGREGATE CRUSHING VALUE TEST (ACV)

3.2.1 Observation

Aggregate Crushing Value test for different type of building debris were conducted based on BS 812, part 110.

Table 3.3 Aggregate Crushing Value Test of Concrete debris

Test No.	1	2
Weight of sample in standard measure (g)	2181	2185
Weight of sample passing 2.36 mm sieve after test (g)	761	767
Weight of sample retained on 2.36 mm sieve after test (g)	1414	1410

Observations of Aggregate Crushing Value Test of RR Masonry, Concrete block and cement plaster debris are tabulated in Appendix 2.

3.2.2 Specimen Calculation

From table 3.3, 2nd set of readings,

Weight of sample in standard measure = 2185 g

Weight of sample passing 2.36 mm sieve after test = 767 g

Weight of sample retained on 2.36 mm sieve after test = 1410 g

Hence, Aggregate Crushing Value of concrete debris = 767/2185 x 100

= 35.1 %

Similarly,

From 1st set of readings, Aggregate Crushing Value = 34.9 %

Hence, Average Aggregate Crushing Value of concrete debris = 35 %

3.2.3 Results

Similarly, calculation was done for RR Masonry debris, concrete block debris and cement plaster separately and results are tabulated below,

Table 3.4 Results of Aggregate Crushing Value Test of different type of debris

Test No.	1	2	Average
Concrete debris	35.1 %	34.9 %	35 %
RR Masonry debris	24.9 %	25.4 %	25 %
Concrete block debris	37.5 %	38.4 %	38 %
Cement plaster debris	Result was unable to obtain		

These results are graphically illustrated in figure 3.3.

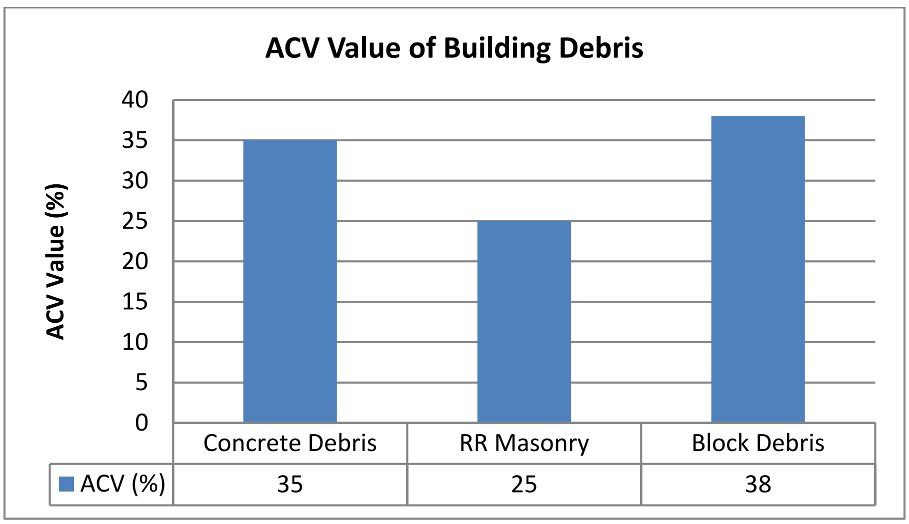


Figure 3.3 Aggregate Crushing Value of different type of debris

3.3 LOS ANGELES ABRATION VALUE TEST (LAAV)

3.3.1 Observation

Los Angeles Abrasion Value test for different type of building debris were conducted based on ASTM C131.

Table 3.5 Los Angeles Abrasive Value Test of Concrete debris

Test No.	1	2
Total Weight of sample (g)	5000	5000
Weight of sample passing 1.7 mm sieve after test (g)	2249	2271
Weight of sample retained on 1.7 mm sieve after test (g)	2658	2699

Observations of Los Angeles Abrasive Value Test of RR Masonry, Concrete block and cement plaster debris are tabulated in Appendix 3.

3.3.2 Specimen Calculation

From table 3.5, 2^{nd} set of readings,

Total weight of sample (W1 g) = 5000 g

Weight retained on 1.7 mm sieve after rotation (W2 g) = 2699 g

Weight passing 1.7 mm sieve after rotation (W2 g) = 2271 g

Hence, Los Angeles Abrasion Value = 45.4 %

Similarly,

From 1^{st} set of readings, Los Angeles Abrasion Value = 44.9 %

Hence, Average Los Angeles Abrasion Value of concrete debris = 45 %

3.3.3 Results

Similarly, calculation was done for RR Masonry debris, concrete block debris and cement plaster separately and results are tabulated below,

Table 3.6 Results of Los Angeles Abrasion Value Test of different type of debris

Test No.	1	2	LAAV (%)
Concrete debris	45.4 %	44.9 %	45 %
RR Masonry debris	31.9 %	30.9 %	31 %
Concrete block debris	70.4 %	69.0 %	70 %
Cement plaster debris	Unable to obtain		

The results of Los Angeles Abrasion Value test of different kind of debris are graphically illustrated in figure 3.4.

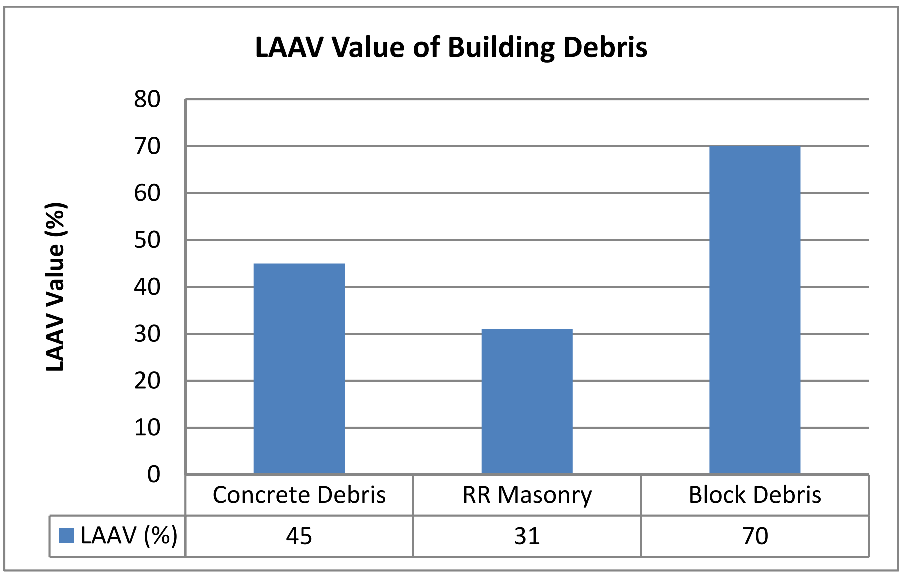


Figure 3.4 Los Angeles Abrasion Value of different type of debris

3.4 WATER ABSORPTION TEST

3.4.1 Observation

Water Absorption test was carried out to random rubble masonry debris based on ASTM C127-77.

Weight of oven dry sample in air = 4624.8 g

Weight of saturated surface dry sample air = 4688.6 g

3.4.2 Calculation

Water absorption $= \frac{(4688.6 - 4624.8)}{4624.8} \times 100$

$= 1.4\ \%$

3.4.3 Results

Water absorption percentage of random rubble masonry debris is 1.4%.

3.5 CONSISTANCY TESTS OF CRUSHED DEBRIS

3.5.1 ATTERBERG LIMIT TEST SAMPLE 1 (CLAY:SOIL:CONCRETE BLOCK = 1:2:3)

3.5.1.1 Observation

Note:

Debris of concrete block, cement plaster and concrete was crushed using crusher separately and then sieved using 50 mm size sieve. More than 50 mm size particles were removed from the sample. At one trial, clay and soil were mixed with crushed debris separately at the ratio of 1: 2: 3 as follows to prepare test samples.

- Sample 1 - Clay: Gravely Soil: Concrete block debris – 1: 2:3
- Sample 2 - Clay: Gravely Soil: Cement Plaster debris – 1: 2:3
- Sample 3 - Clay: Gravely Soil: Concrete debris – 1: 2:3

To compare the properties of crushed debris with soil properties, fine particle tests were carried out on sample 1, sample2, sample 3 and natural soil separately.

Table 3.7 Atterberg Limit Test of Sample 1

	Liquid Limit Test					**Plastic Limit Test**	
Sample No.	1	2	3	4	5	6	7
Number of Blows	35	27	21	16	11		
Wt. of dish /(g)	18.2	18.23	11.65	13.94	12.21	20.72	20.48
Wt. of wet soil and dish /(g)	32.38	33.02	24.22	23.00	26.05	33.95	31.74
Wt. of dry soil and dish/(g)	29.74	30.25	21.80	21.22	23.24	31.76	29.86

3.5.1.2 SPECIMEN CALCULATION

3.5.1.2 (a) Calculation of Liquid Limit

Consider 2^{nd} set of reading from table No. 3.7

Weight of dish = 18.23 g

Weight of wet soil and dish = 33.02 g

Weight of dry soil and dish = 30.25 g

Weight of water = 33.02 – 30.25

= 2.77 g

Weight of dry soil = 30.25 – 18.23

= 12.02 g

Moisture content = $\frac{\text{Wt. of water}}{\text{Wt. of soil}}$ x 100

Hence, Moisture Content = 23.0%

Similarly, liquid limit is calculated for other set of readings and graph was plotted for No. of blows Vs moisture content.

Table 3.8 Table for no. of blows Vs moisture content of Sample 1

Sample No.	1	2	3	4	5
No. of blows	35	27	21	16	11
Moisture Content	22.9	23.0	23.8	24.5	25.0

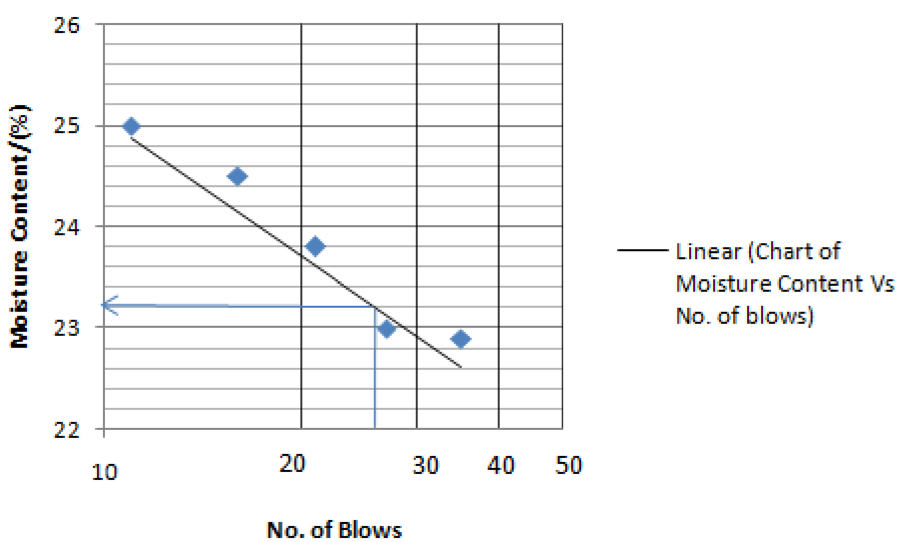


Figure 3.5 Graph for no. of blows Vs. moisture content of Sample 1

From Figure 3.5,

Liquid Limit = 23%

3.5.1.2 (b) Calculation of Plastic Limit

Consider 6th set of reading from table No. 3.7

Weight of dish = 20.72 g

Weight of wet soil and dish = 33.95 g

Weight of dry soil and dish = 31.76 g

Weight of water = 33.95 – 31.76

= 2.19 g

Weight of dry soil = 31.76 – 20.72

= 11.04 g

Moisture content $= \frac{\text{Wt. of water}}{\text{Wt. of soil}} \times 100$

Hence, Plastic Limit = 19.8%

Similarly, plastic limit is calculated for other set of readings and tabulated as below,

Table 3.9 Table for Plastic Limit of Sample 1

Sample No.	6	7
Plastic Limit	19.8	20.0
Avr. Plastic Limit (PL)	20	

Plasticity Index (PI) = Liquid Limit – Plastic Limit

= 23-20

= 3 %

Observations and Calculations of Atterberg Limit Test of soil, sample 2 and sample 3 are illustrated in Appendix 4

3.5.2 Results

Table 3.10 Results of Atterberg Limit Test

Test Sample	Soil	Sample 1 (Clay:Soil:Concrete Block= 1:2:3)	Sample 2 (Clay:Soil:Plaster = 1:2:3)	Sample 3 (Clay:Soil:Concrete = 1:2:3)
Liquid Limit (LL)	30	23	24	25
Plastic Limit (PL)	20	20	19	19
Plasticity Index (PI)	10	3	5	6

The results of Atterberg limit test of different type of crushed debris are graphically shown in figure 3.6.

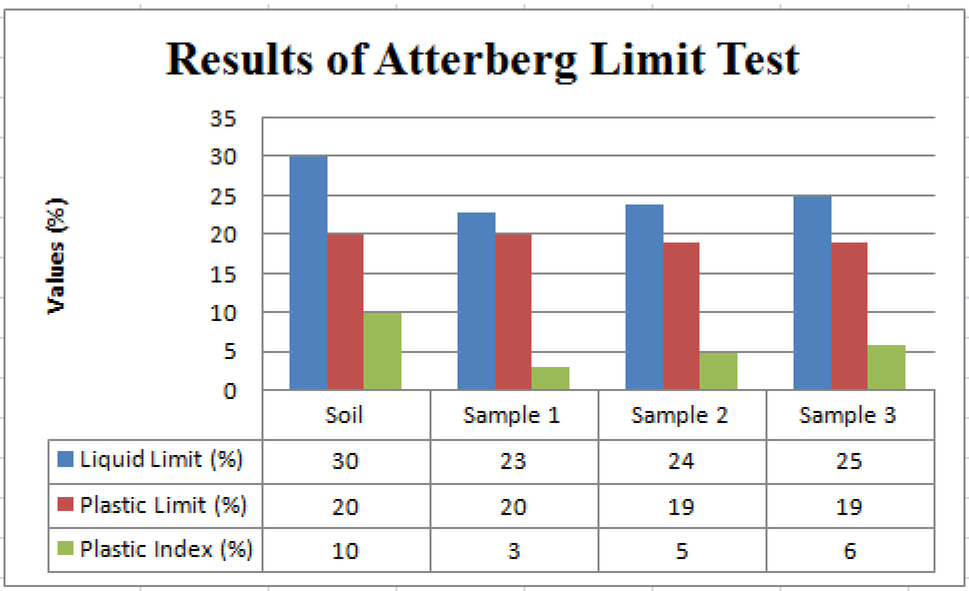


Figure 3.6 Results of Atterberg Limit Test

3.6 MODIFIED COMPACTION TEST

3.6.1 MODIFIED COMPACTION TEST FOR MIX A

3.6.1.1 Observations

Table 3.11 Modified Compaction Test of Sample 1

Test No.	1	2	3	4
Wt. of mould + wet soil/(g)	10423	10547	10708	10716
Wt. of mould/(g)	5625	5625	5625	5625

Test No.	1	2	3	4
Wt. of dish/(g)	35.1	23.4	25.7	33.4
Wt. of dish + wet soil/(g)	358.7	343.8	328.0	454.2
Wt. of dish + dry soil/(g)	338	321.4	303.8	416.3

3.6.1.2 Specimen Calculation

Consider 1st set of reading from table 3.11

Weight of mould = 5625 g

Weight mould and wet soil = 10423 g

Weight of wet soil = 4798 g

Hence, wet density = $\frac{4798}{2305}$

= 2.08 g/cm^3 (2080 kg/m^3)

Weight of dish = 35.1 g

Weight of dish and wet soil = 358.7 g

Weight of dish and dry soil = 338.0 g

Weight of water = 20.7 g

Weight of dry soil = 302.9 g

Hence, moisture content = 6.8%

Dry density (Υ_d) = $\underline{\Upsilon_t}$

$1{+}w_c$

= 2.08/ (1+0.068)

= 1.95 g/cm^3 (1950 kg/m^3)

Similarly, moisture content and dry density are calculated for other set of readings and graph is plotted for moisture content Vs dry density.

Table 3.12 Table for moisture content Vs. dry density of Sample 1

Test No.	**1**	**2**	**3**	**4**
Wt. of wet soil/(g)	4798	4922	5083	5091
Wet density	2.08	2.14	2.21	2.21
Wt. of water/(g)	20.7	22.4	24.2	37.9
Wt. of dry soil/(g)	302.9	298.0	278.1	382.9
Moisture content (%)	6.8	7.5	8.7	9.9
Dry density (g/cm^3)	1.95	1.99	2.03	2.01

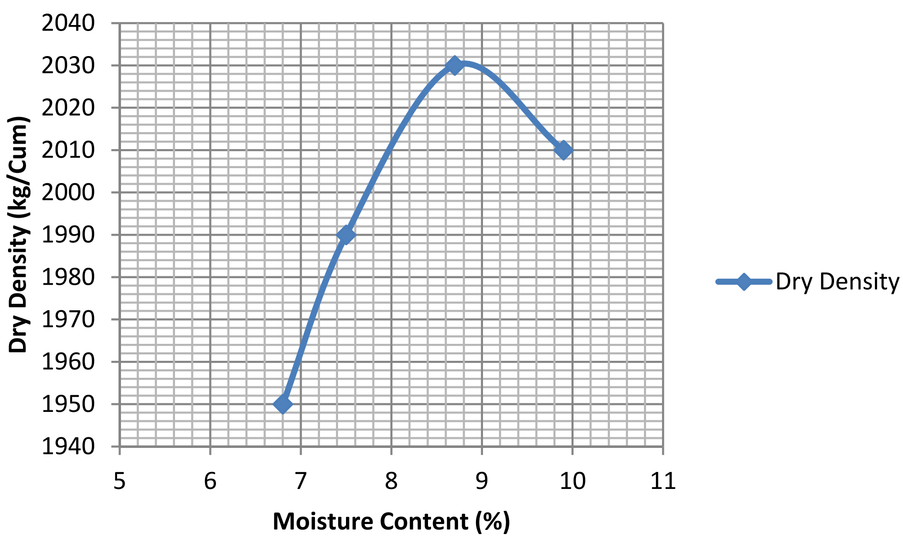


Figure 3.7 Graph for moisture content Vs. dry density of Sample 1

From figure 3.7,

Maximum dry density = 2030 kg/m^3

Optimum moisture content = 9.0%

Observations and Calculations of Modified Compaction Test of sample 2, sample 3 and soil are illustrated in Appendix 5

3.6.5 Results

Table 3.13 Results of Modified Compaction Test

Test No.	Soil	Sample 1 (Clay:Soil:Concrete Block= 1:2:3)	Sample 2 (Clay:Soil:Plaster = 1:2:3)	Sample 3 (Clay:Soil:Concrete = 1:2:3)
Maximum Dry Density (MDD) (kg/m^3)	2120	2030	2000	2020
Optimum Moisture Content (OMC) (%)	7.9	9.0	7.8	8.0

These results are graphically illustrated in figure 3.8.

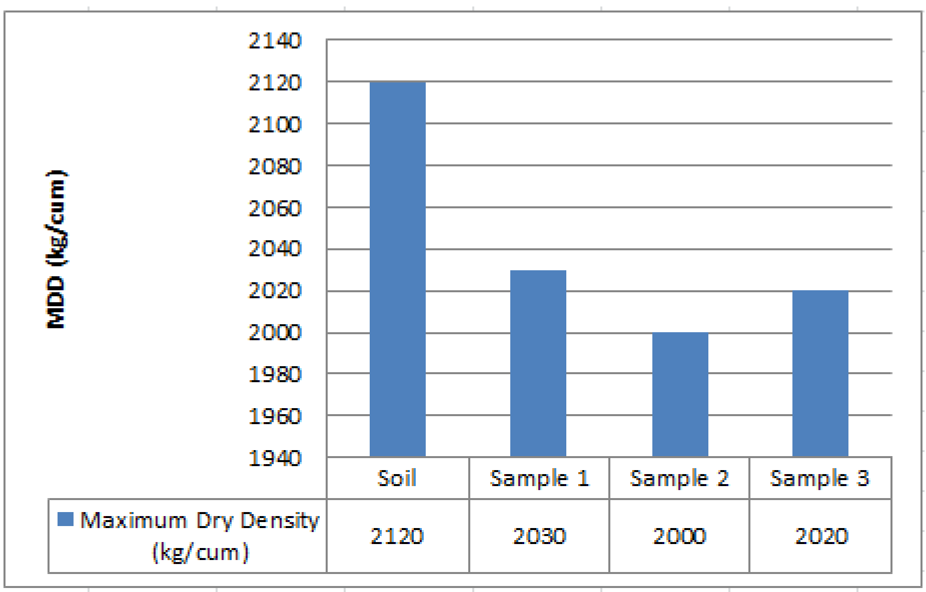


Figure 3.8 Results of Modified Compaction Test.

3.7 CALIFORNIA BEARING RATIO TEST

3.7.1 CALIFORNIA BEARING RATIO TEST FOR CLAY, GRAVEL MIX

3.7.1.1 Observation

Table 3.14 Reading of California Bearing Ratio Test of Sample 1

Penetration	Load Dial Readings	
/(mm)	Top	Bottom
0.00	0	0
0.25	8	3
0.50	26	11
0.75	58	28
1.00	104	58
1.25	152	116
1.50	208	178
1.75	265	272
2.00	300	365
2.25	335	448
2.50	370	515
2.75	400	574
3.00	425	616
3.25	453	662
3.50	480	698
3.75	502	715
4.00	525	748
4.25	545	775
4.50	562	796
4.75	580	820
5.00	600	838
5.25	618	865
5.50	634	885
5.75	652	905
6.00	669	924

3.7.1.2 Specimen Calculation

Consider 5^{th} set of readings from table 3.14

Depth of penetration = 1.0 mm

Load dial readings (Top) = 104

Load dial readings (Bottom) = 58

Ring factor = 0.025 kN/Div

Load on top = 104 x 0.025

= 2.6 kN

Load on bottom = 58 x 0.025

= 1.45 kN

Table 3.15 Table of Penetration Vs Load for Sample 1

Penetration	**Load /(kN)**	
/(mm)	**Top**	**Bottom**
0.00	0.000	0.000
0.25	0.200	0.075
0.50	0.650	0.275
0.75	1.450	0.700
1.00	2.600	1.450
1.25	3.800	2.900
1.50	5.200	4.450
1.75	6.625	6.800
2.00	7.500	9.125
2.25	8.375	11.200
2.50	9.250	12.875
2.75	10.000	14.350
3.00	10.625	15.400
3.25	11.325	16.550
3.50	12.000	17.450
3.75	12.550	17.875
4.00	13.125	18.700
4.25	13.625	19.375
4.50	14.050	19.900
4.75	14.500	20.500
5.00	15.000	20.950
5.25	15.450	21.625
5.50	15.850	22.125
5.75	16.300	22.625
6.00	16.725	23.100

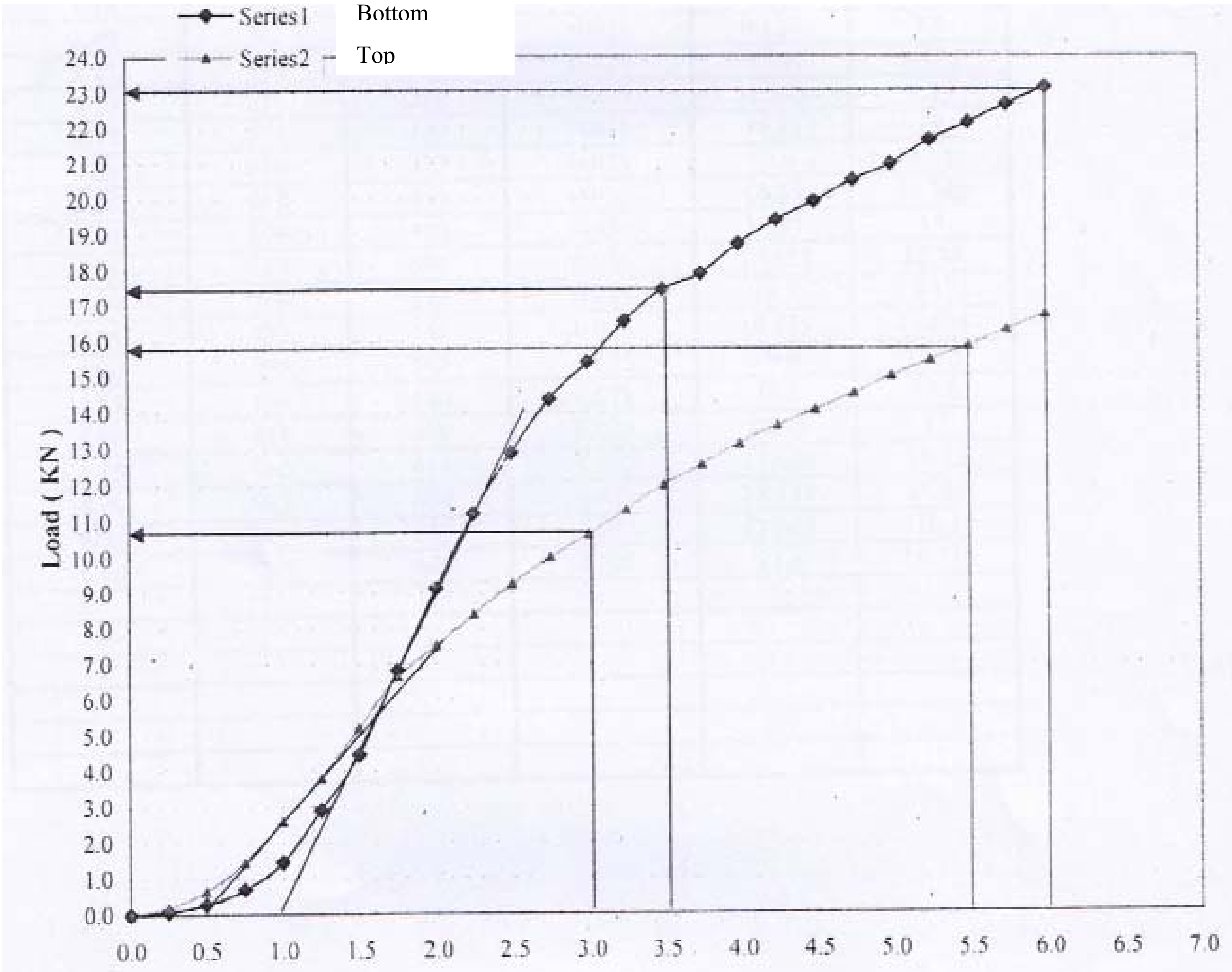


Figure 3.9 Graph of Penetration Vs Load for Sample 1

3.7.1.3 Calculation

For top, from figure 3.9,

Load at 2.5 mm penetration	= 10.7 kN
Load at 5.0 mm penetration	= 15.8 kN
Standard load at 2.5 mm penetration	= 13.24 kN
Standard load at 5.0 mm penetration	= 20.00 kN
California Bearing Ratio at 2.5 m penetration	$= \frac{10.7 \times 100}{13.24}$

= 81 %

California Bearing Ratio at 5.0 m penetration = $\frac{15.8 \times 100}{20.00}$

= 79 %

Similarly, for bottom,

California Bearing Ratio at 2.5 m penetration = $\frac{17.5 \times 100}{13.24}$

= 132 %

California Bearing Ratio at 5.0 m penetration = $\frac{23.0 \times 100}{20.00}$

= 115 %

Hence, CBR Value = 80%

Observations and Calculations of California Bearing Ratio Test of sample 2, sample 3, Random Rubble Masonry and soil debris are illustrated in Appendix 6

3.7.1.4 Results

Table 3.16 Results of California Bearing Ratio Test

Sample	**CBR (%)**
Soil	50
Sample 1(Clay:Soil: Concrete Block)	80
Sample 2(Clay:Soil:Plaster)	130
Sample 3 (Clay:Soil: Concrete)	65
RR Masonry Debris	86

CHAPTER 4

4.0 RESULTS AND ANALYSIS

4.1 RESULTS

Table 4.1 Summary of Aggregate Tests Results

Sample	AIV	ACV	LAAV	CBR	Water absorption
Concrete Debris	35	35	45	-	-
RR Masonry	25	25	31	86	1.4
Concrete block	37	38	70	-	-
Ct. plaster	Unable to prepare sample			-	-

The results of coarse particle test of different type of building debris are illustrated in figure 4.1.

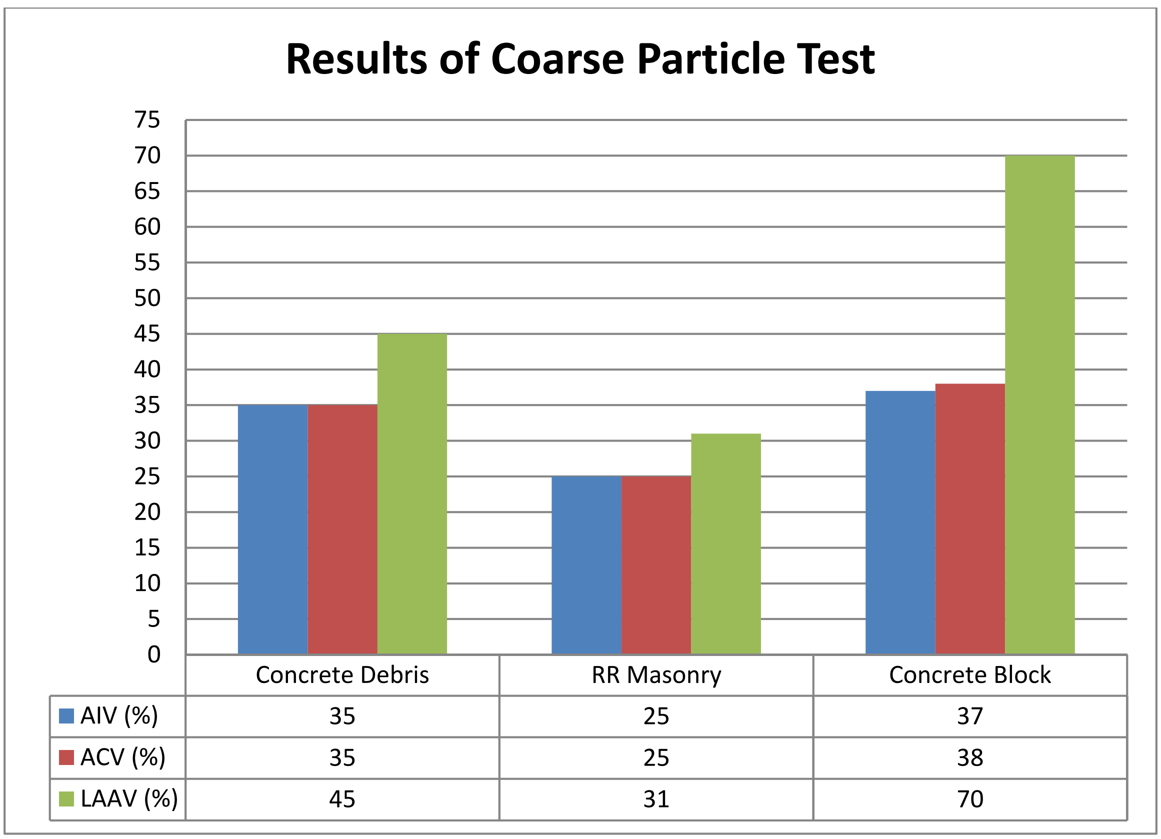


Figure. 4.1 Results of Coarse Particle Test

Figure 4.1 shows results of coarse particle test on debris of concrete, random rubble masonry and concrete block wall. Aggregate Impact Values of Concrete debris and concrete block wall debris are 35% and 37% whereas upper bound value of AIV for road base material is 30% according to the Standard Specification for Construction and Maintenance (SSCM) for Roads and Bridges.

Aggregate Crushing Value obtained from Aggregate Crushing Test on concrete debris and concrete block wall debris as per BS 812 are 35% and 38% whereas AIV of road base material must be less than 35%.

Los Angeles Aggressive Values of concrete debris and concrete block wall debris are 45% and 70% which are greater than the LAAV upper limit of 40% for road base material according to the SSCM.

Aggregate Impact Value, Aggregate Crushing Value and Los Angeles Aggressive value of RR Masonry debris are 25 %, 25 % and 31 % which satisfies the criteria of road base material according to the SSCM for Roads and Bridges.

Test sample from plaster debris for coarse particle tests was unable to prepare since it became finer particle when it was crushed.

Water absorption and CBR value of RR Masonry debris are 1.4 and 86% respectively.

Considering the above results obtained from the coarse particle test on concrete debris, RR masonry debris, plaster and concrete block wall debris, RR masonry debris only satisfies the criteria of road base material.

Table 4.2 Summary of fine particles tests results

Sample	LL (%)	PL (%)	PI (%)	OMC (%)	MDD (kg/m^3)	CBR (%)
Soil	30	20	10	7.9	2120.0	50
Sample 1	23	20	3	9.0	2030.0	124
Sample 2	24	19	5	7.8	2000.0	155
Sample 3	26	19	7	8.0	2020.0	65

Sample 1 - Clay: Gravely Soil: Concrete block debris – 1: 2:3
Sample 2 - Clay: Gravely Soil: Cement Plaster debris – 1: 2:3
Sample 3 - Clay: Gravely Soil: Concrete debris – 1: 2:3

The summary of fine particle test results are graphically illustrated in figure 4.2, 4.3 & 4.4.

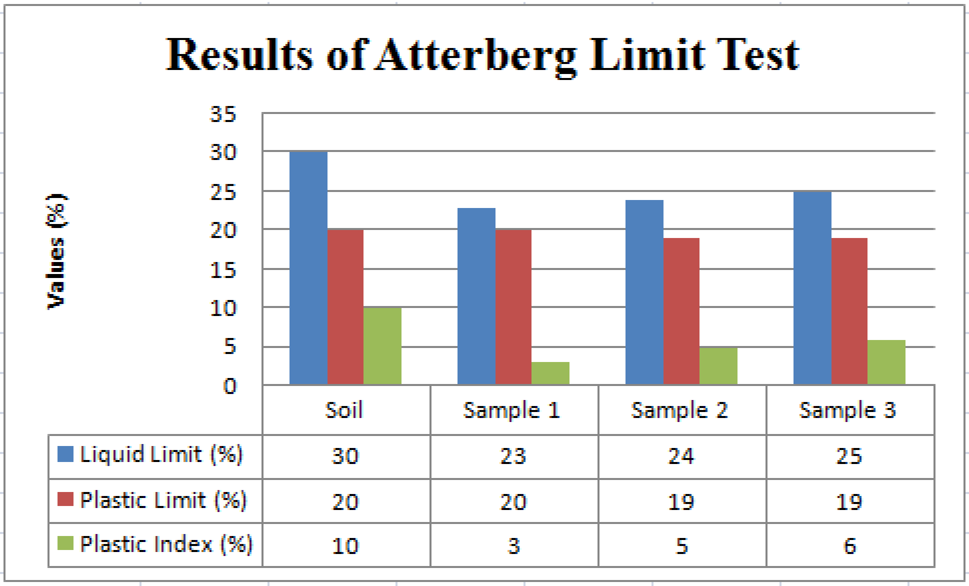


Figure 4.2 – Results of Atterberg Limit Test

The figure 4.2 illustrates the results of Atterberg Limit Test on natural soil, sample 1, sample 2 and sample 3. Sample 1, sample 2 and sample 3 are mixture of clay, soil and crushed debris of concrete block, plaster and concrete respectively. The sample mix ratio of clay, soil and crushed debris is 1:2:3.

Liquid limit, Plastic limit and Plastic Index of soil are 30%, 20% and 10% respectively.

Liquid Limits of sample 1, sample 2 and sample 3 are 23%, 24% and 25% which are lesser than the upper limit of 40% given in the SSCM. Plastic Index of sample 1, sample 2 and sample 3 are 3%, 5% and 6%.

Building debris is a non plastic material while clay soil is plastic. From the results of atterberg limit test on above samples, it can be observed that the Plastic Index of building debris can be improved by adding clay particles. Liquid limit of soil can also be reduced when it is mixed with building debris.

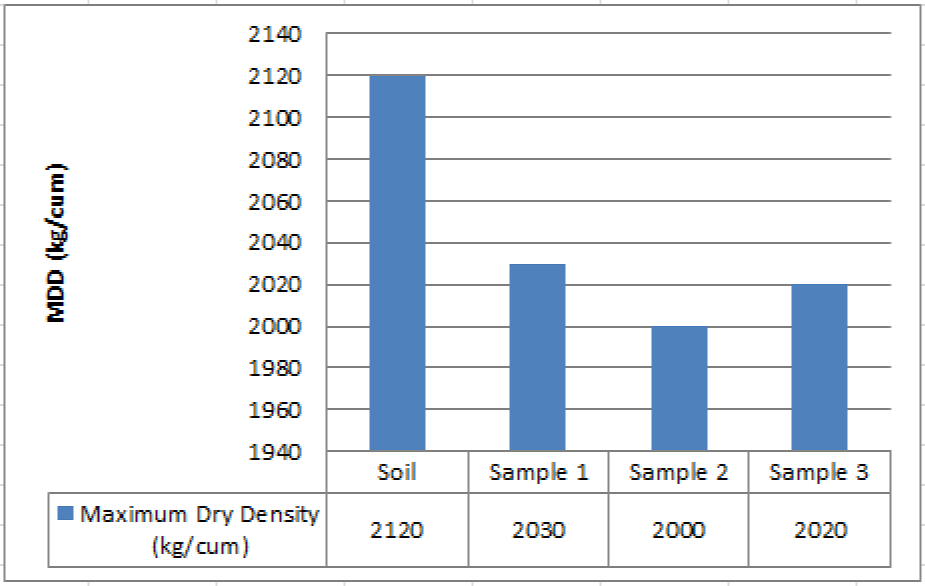


Figure 4.3 – Results of Modified Compaction Test

The above figure 4.3 illustrates the results of Modified Compaction Tests on natural soil, sample 1, sample 2 and sample 3. Maximum Dry Density (MDD) of sample 1, sample 2 and sample 3 are 2030 kg/cum, 2000 kg/cum and 2020 kg/cum respectively. These MDD values are above the lower limit of 1750 kg/cum according to SSCM for Roads and Bridges.

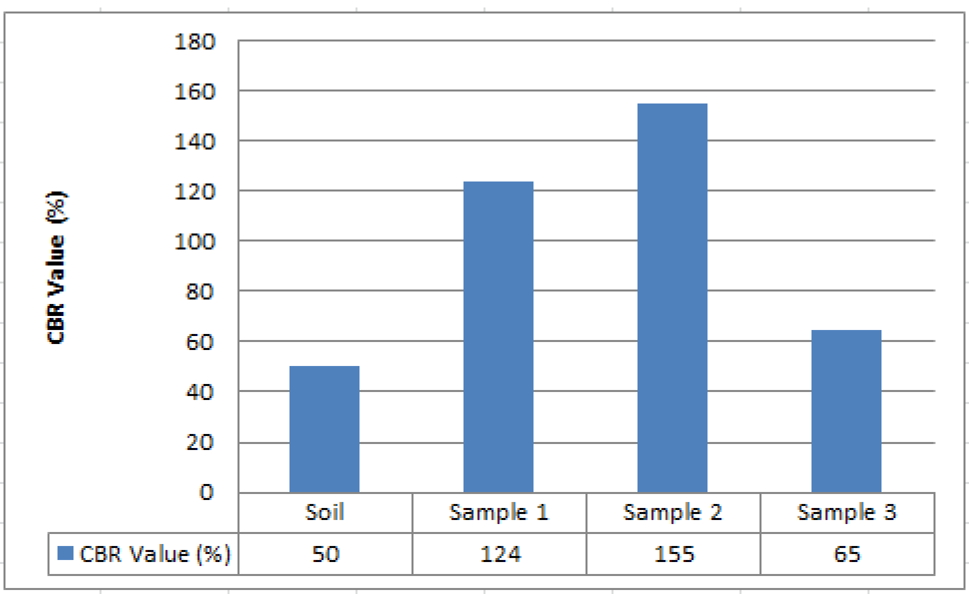


Figure 4.4 – Results of CBR Test

The figure 4.4 shows results of California Bearing Ratio (CBR) of natural soil, sample 1, sample 2 and sample 3. CBR value of sample 1, sample 2 and sample 3 are 124%, 155% and 65% respectively. These values are above the lower limit of 30% given in the SSCM for road construction fine material.

The CBR test results show that the CBR value of natural soil is 50% and this can be improved when building debris is mixed.

From the above fine particle tests on sample 1, sample 2 and sample 3, it can be observed that all three samples' engineering properties satisfies the criteria given in the SSCM for road construction fine particle material.

4.2 ANALYSIS

As per the ICTAD Publication for Standard Specifications for Construction and Maintenance of Roads and Bridges (SSCM), June 2009 road base material should have following properties,

Table 4.3 Criteria for Road Base Material

	Properties
AIV (%)	< 30
ACV (%)	< 35
LAAV (%)	< 40
CBR (%)	> 80
Water Absorption (%)	< 2

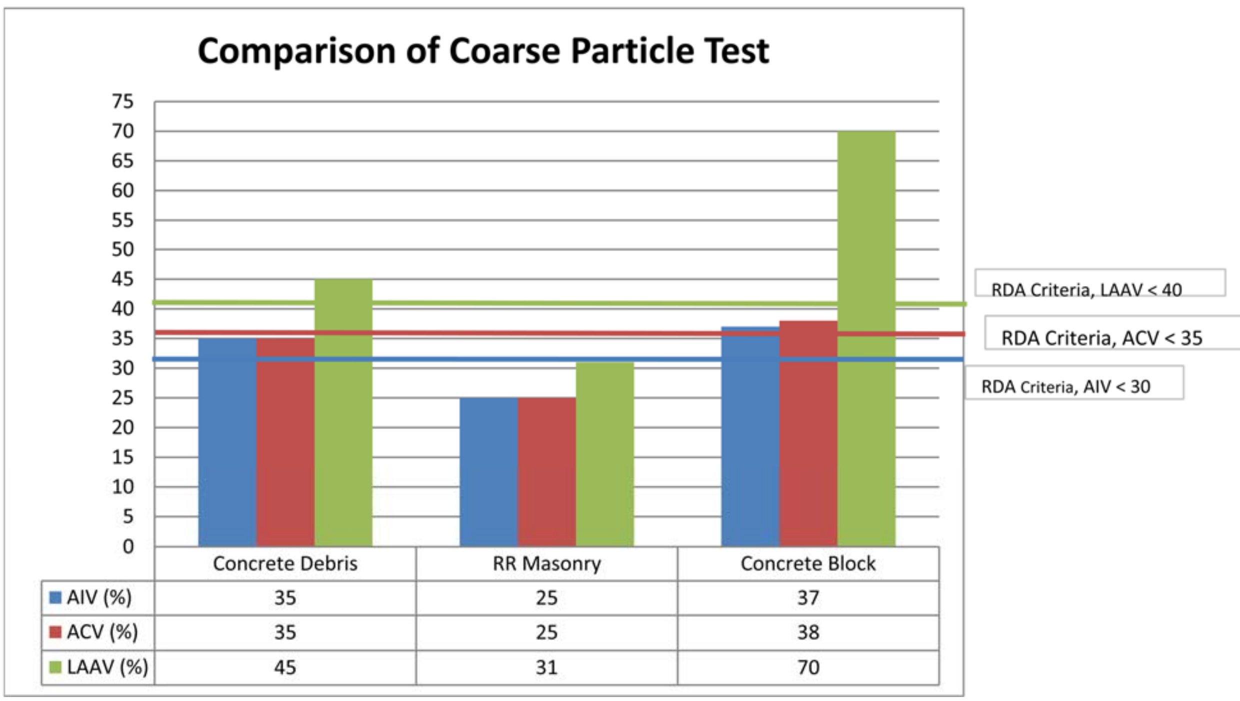


Figure 4.5 Comparison of Coarse Particle Test

The above figure 4.5 illustrates the comparison of engineering properties of building debris and criteria of road base material. Considering the test results tabulated in Table no. 4.1, figure 4.5 and criteria given in table no. 4.3 for road base material, it can be observed that except RR masonry debris, debris of concrete, plaster and concrete block do not satisfy the properties limit of road base material based on SSCM for Roads and Bridges. Hence, Random Rubble Masonry debris only can be directly used for road base construction.

As mentioned in the SSCM, June 2009 fine particle material used in road construction should have following properties,

Table 4.4 Criteria for Fine Particle Material in Road Construction

	Properties			
	Liquid Limit (%)	Plasticity Index (%)	Maximum Dry Density (kg/m^3)	CBR (%)
Upper Sub Base	< 40	< 15	> 1750	> 30
Lower Sub Base	< 40	< 15	> 1650	> 15
Embankment – Type I	< 50	< 25	> 1600	> 7
Embankment – Type II	< 55	< 25	> 1500	> 5
Shoulder	< 55	6 - 25	> 1600	> 15
Gravel Road – top layer	< 55	6 - 25	> 1650	> 15
Gravel Road – intermediate layer	< 50	6 - 25	> 1650	> 8

Sample 1 - Clay: Gravely Soil: Concrete block debris – 1: 2:3
Sample 2 - Clay: Gravely Soil: Cement Plaster debris – 1: 2:3
Sample 3 - Clay: Gravely Soil: Concrete debris – 1: 2:3

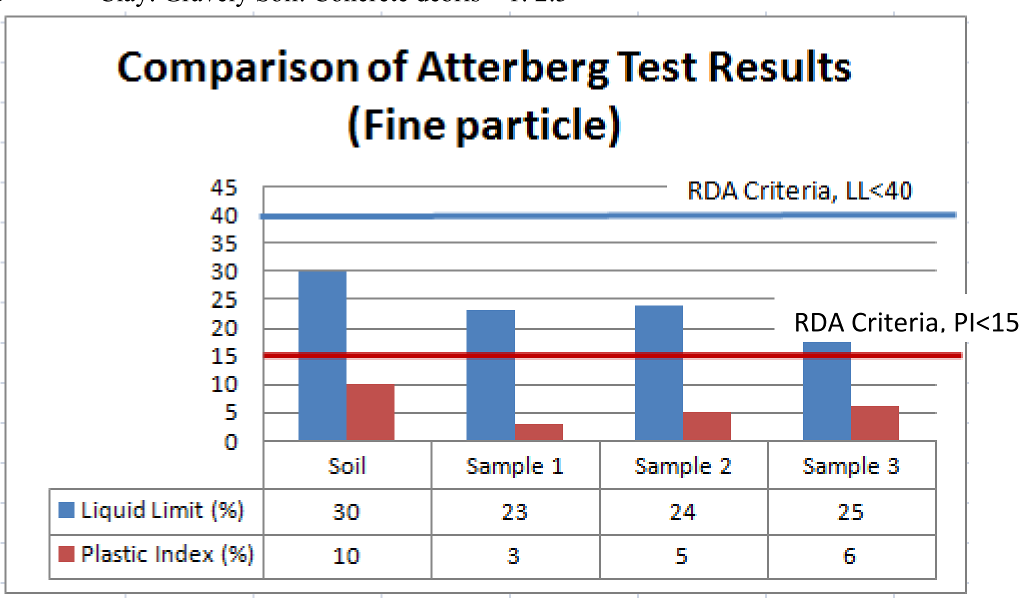


Figure 4.6 Comparison of Atterberg Test Results

The above figure 4.6 illustrates the comparison of atterberg limit test results and standard properties of road construction fine particle material. It can be noted that the Liquid Limit and Plastic Index of sample 1, sample2 and sample 3 are within the limit provided in the SSCM for Roads & Bridges. Liquid Limit and Plastic Index of fine particles road construction material should be less than 40% and 15% respectively.

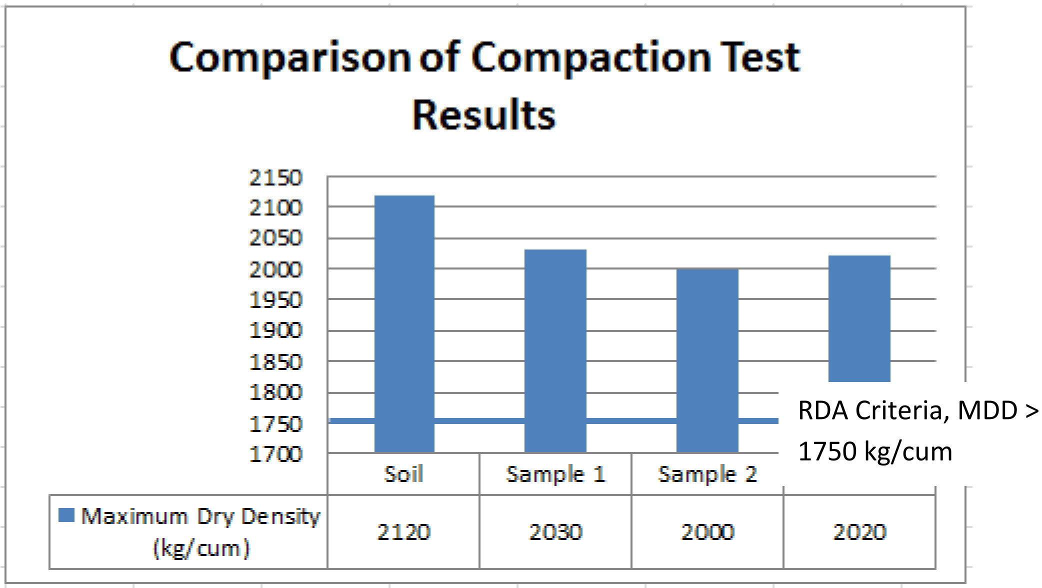


Figure 4.7 Comparison of Compaction Test Results

The figure 4.7 shows comparison of compaction test results and standard properties of fine particle road construction material. According to SSCM for Roads and Bridges, the maximum dry density of fine particle construction material must be greater than 1750 kg/cum. As per the above results obtained, all three samples satisfy the required criterion.

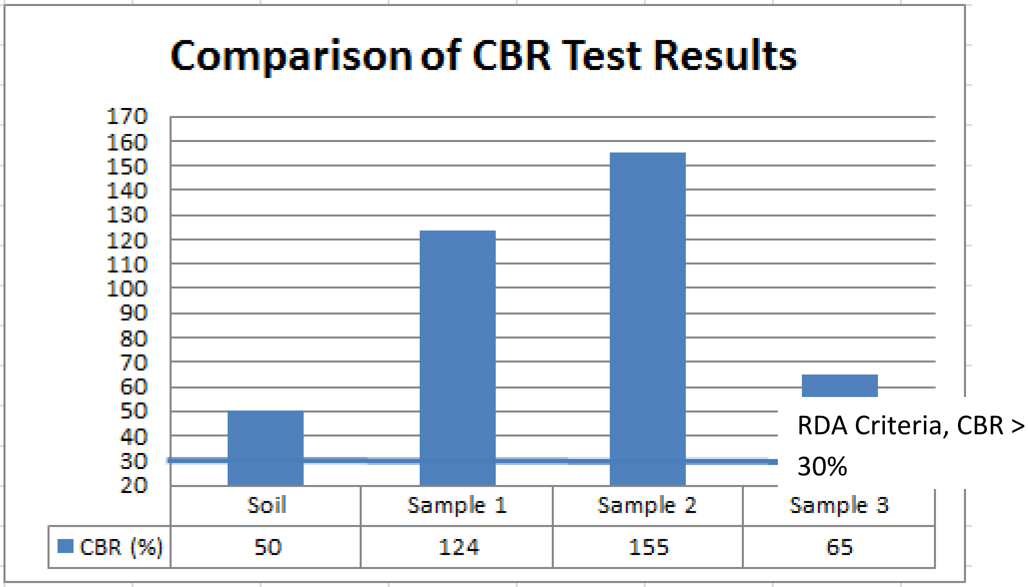


Figure 4.8 Comparison CBR Test Results

The figure 4.8 shows comparison of CBR test results and standard CBR value of fine particle road construction material. The 4 days soaked CBR value of fine particle construction material must be greater than 30% according to SSCM for Roads and Bridges. From the above figure, it can be observed that all three samples have very high CBR value.

Considering the fine particles tests results in table 4.2, figure 4.6, 4.7 & 4.8 and criteria given in Table 4.4, the mix of clay, soil and crushed building debris of concrete block, plaster and concrete satisfy the all criteria given in the table no. 4.4 as per SSCM for Bridges & Roads and can be replaced for fine particle material in road construction.

CHAPTER 5

5.1 CONCLUSION

According to the coarse particle tests carried out on debris of random rubble masonry, concrete, concrete block and plaster as per the standards; random rubble masonry debris only can be directly used for road base construction after removing cement sand plaster. Other debris of concrete, concrete block and plaster debris were not satisfied the criteria of road base material provided in the standard specification for construction and maintenance of roads and bridges.

When maintain the required gradation for road base material as per SSCM, more than 80% of CBR value can be achieved in random rubble masonry debris. The water absorption of random rubble masonry debris is 1.4% (less than 2%) and satisfied the criteria of road base material properties.

Crushed building debris of plaster, block masonry, concrete debris is suitable for sub base and Embankment construction as its properties are within the limit provided in the SSCM for roads and bridges.

Crushed building debris of plaster, block masonry, concrete debris is suitable for shoulder and surfacing of 'D' and 'E' class earthen road after adding clay particles. The mix proportion of construction material shall be prepared at the ratio of 1:2:3 (clay: soil: debris). During the preparation of sample suitable material gradation shall be maintain to achieve required compaction and CBR.

As per the test carried out on various kind of debris, the utilization of building debris in construction of different road components shall be summarized as follows,

Table 5.1 Summary of Compliance in Road Construction

Debris		**Usage in Road Construction**			
	Road Base	Sub base	Shoulder	Embankment	Surface of D & E class roads
Random Rubble Masonry Debris	Applicable	-	-	-	-
Concrete Block debris	Not Applicable	-	-	-	-
Concrete Debris	Not Applicable	-	-	-	-

Plaster Debris	Not Applicable	-	-	-	-
Mix of clay : soil: crushed concrete block debris (1: 2: 3)	-	Applicable	Applicable	Applicable	Applicable
Mix of clay : soil: crushed ct. plaster debris (1: 2: 3)	-	Applicable	Applicable	Applicable	Applicable
Mix of clay : soil: crushed concrete debris (1: 2: 3)	-	Applicable	Applicable	Applicable	Applicable

Since, it is new method of road construction in Sri Lanka and mix percentage of building debris, soil and clay may vary according to the properties of construction debris, type of soil, class of roads and type of usage in road construction, the following laboratory and field tests are proposed based on ICTAD publication, Standard Specification for Construction and Maintenance of Roads and Bridges to carry out prior to site construction in order to ensure the quality of works.

1. Prior to site construction, laboratory testing shall be carried out to determine the mix design.

2. Any extraneous matter shall be removed from the building debris. Then, it shall be crushed to fine particle by means of crusher.

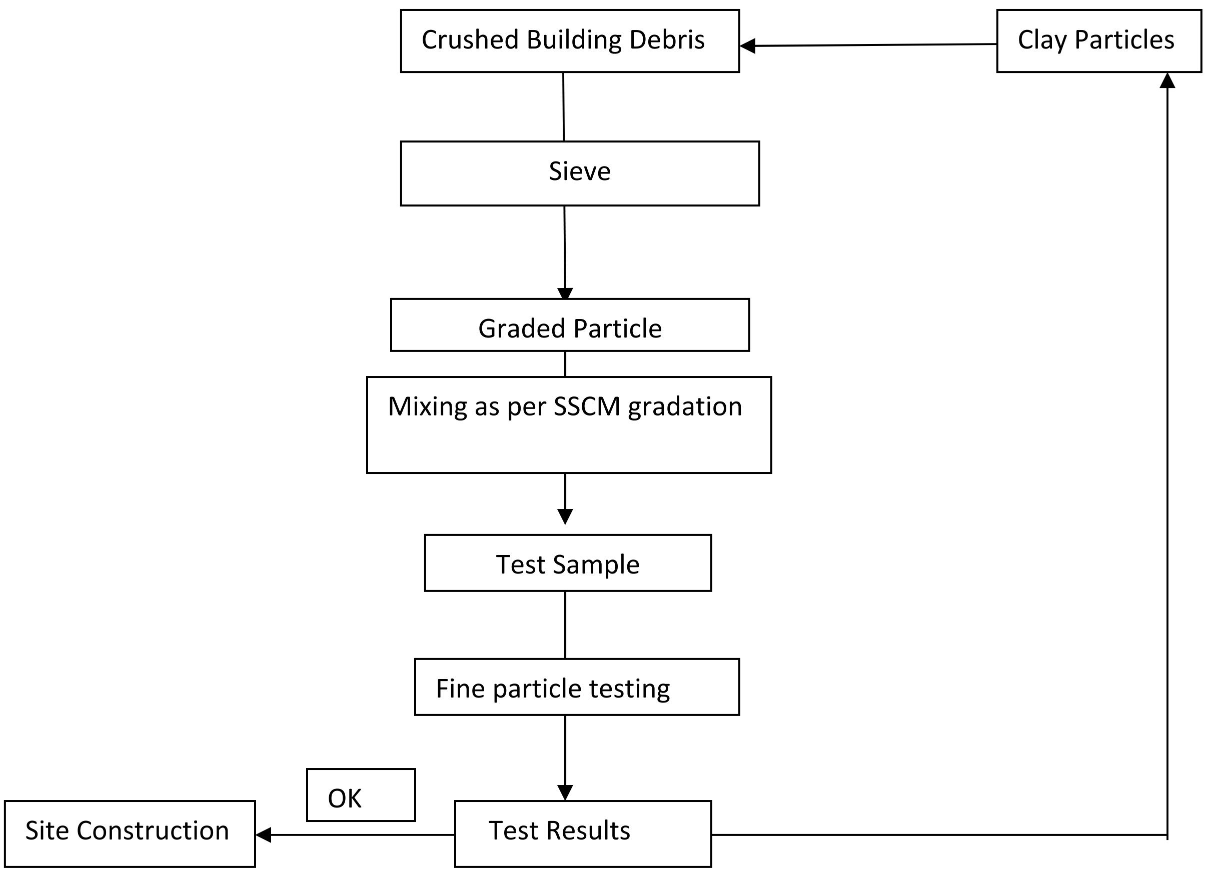
3. Certain percentage of clay particles shall be added to increase the plasticity of mix for usage of shoulder and surfacing of earthen road. (Trial).

4. The mixture of crushed particles and clay shall be graded using different size of sieves.

5. As per grading requirements for the combined aggregate as per SSCM, June 2009, laboratory sample shall be prepared.

6. Fine particles test such as compaction test, CBR test and atterberg test shall be carried out to determine the property of sample.

7. If it is satisfied the criteria given in the SSCM, June 2009, this mix design shall be carried out at the field. Otherwise, mix proportionate shall be changed and carried out from steps 3 to steps 6



8. According to the results obtained from the laboratory test, construction material shall be prepared at the site.

9. Field trial test shall be carried out before the construction work to determine the effective thickness of compaction layer, rolling pattern and number of passes.

10. Site construction shall be carried out as per the results of Field trial test.

Appendix1

Observation of Aggregate Impact Value Test

Table A1.1 Reading of Aggregate Impact Value Test of RR masonry debris

Test No.	**1**	**2**
Weight of sample (g)	303.4	303.4
Weight of sample passing 2.36 mm sieve after test (g)	74.7	77.0
Weight of sample retained on 2.36 mm sieve after test (g)	228.4	226.5

Table A1.2 Reading of Aggregate Impact Value Test of concrete block debris

Test No.	1	2
Weight of sample (g)	267.5	267.5
Weight of sample passing 2.36 mm sieve after test (g)	98.5	99.6
Weight of sample retained on 2.36 mm sieve after test (g)	168.5	167.4

Note: Plaster debris sample was not be prepared for Aggregate Impact Value Test as it was broken into small particles when preparing sample.

Appendix2

Observation of Aggregate Crushing Value Test

Table A2.1 Reading of Aggregate Crushing Value Test of RR Masonry debris

Test No.	1	2
Weight of sample in standard measure (g)	2185	2189
Weight of sample passing 2.36 mm sieve after test (g)	546	556
Weight of sample retained on 2.36 mm sieve after test (g)	1634	1629

Table A2.2 Reading of Aggregate Crushing Value Test of Concrete block debris

Test No.	1	2
Weight of sample in standard measure (g)	2175	2178
Weight of sample passing 2.36 mm sieve after test (g)	815	836
Weight of sample retained on 2.36 mm sieve after test (g)	1335	1339

Note: Plaster debris sample was not be prepared for Aggregate Crushing Value Test as it broken to small particles when preparing sample

Appendix3

Observation of Los Angeles Abrasion Value Test

Table A3.1 Reading of Los Angeles Abrasive Value Test of RR Masonry debris

Test No.	1	2
Total Weight of sample (g)	5000	5000
Weight of sample passing 1.7 mm sieve after test (g)	1596	1544
Weight of sample retained on 1.7 mm sieve after test (g)	3400	3449

Table A3.2 Reading of Los Angeles Abrasive Value Test of concrete block debris

Test No.	1	2
Total Weight of sample (g)	5000	5000
Weight of sample passing 1.7 mm sieve after test (g)	3520	3450
Weight of sample retained on 1.7 mm sieve after test (g)	1450	1549

Note: Plaster debris sample was not be prepared for Los Angeles Abrasive Value Test as it broken to small particles when preparing sample.

Appendix 4

Observations and Calculation of Atterberg Limit Test

A4.1 Atterberg Limit Test for Sample 2 (Clay: Soil: Plaster = 1:2:3)

Table A4.1 Reading of Atterberg Limit Test of Sample 2

	Liquid Limit Test					**Plastic Limit Test**	
Sample No.	1	2	3	4	5	6	7
Number of Blows	38	32	26	18	10		
Wt. of dish /(g)	11.64	17.38	17.95	16.48	16.32	16.75	20.35
Wt. of wet soil and dish /(g)	23.23	29.01	29.50	28.45	30.35	29.45	31.97
Wt. of dry soil and dish/(g)	21.08	26.83	27.30	26.14	27.40	27.42	30.13
Wt. of water/(g)	2.15	2.18	2.20	2.31	2.95	2.03	1.84
Wt. of dry soil/(g)	9.44	9.45	9.35	9.66	11.08	10.67	9.78
Moisture Content (%)	22.8	23.1	23.5	23.9	26.6	19.0	18.8

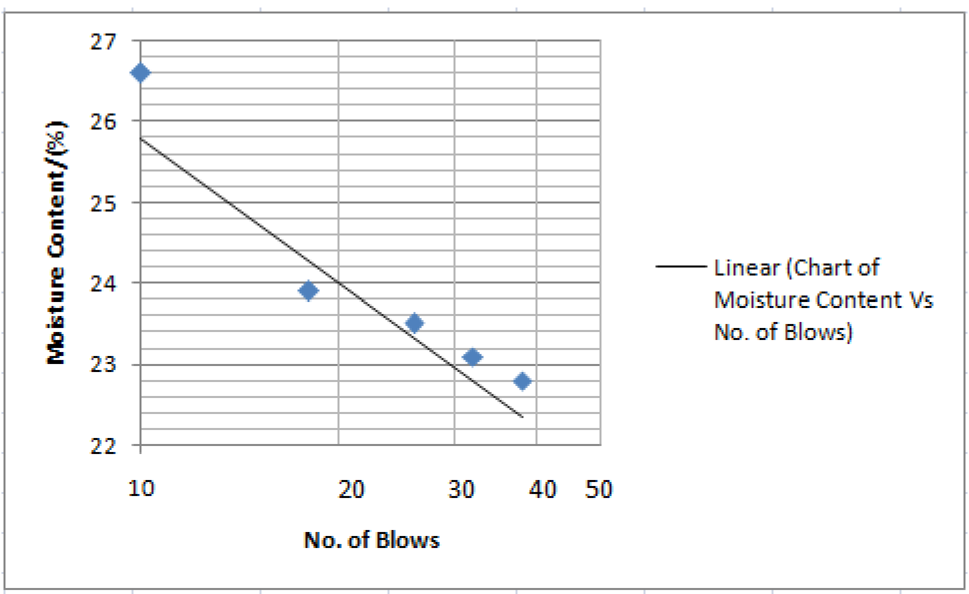


Figure A4.1 Graph for no. of blows Vs. moisture content of Sample 2

From figure A4.1,

Liquid Limit = 24 %

Table A4.2 Table for Plastic Limit of Sample 2

Sample No.	6	7
Moisture content	19.0	18.8
Plastic Limit (PL)	19.0	

Plasticity Index = 5.0

A4.2 Atterberg Limit Test for Sample 3 (Clay: Soil: Concrete = 1:2:3)

Table A4.3 Reading of Atterberg Limit Test Sample 3

	Liquid Limit Test					**Plastic Limit Test**	
Sample No.	1	2	3	4	5	6	7
Number of Blows	48	30	22	17	12		
Wt. of dish /(g)	14.86	17.40	18.23	11.76	15.03	20.36	20.55
Wt. of wet soil and dish /(g)	28.43	28.57	33.25	25.50	26.69	35.42	34.94
Wt. of dry soil and dish/(g)	25.82	26.36	30.20	22.61	24.20	32.97	32.64
Wt. of water/(g)	2.61	2.21	3.05	2.89	2.49	2.45	2.30
Wt. of dry soil/(g)	10.96	8.96	11.97	10.85	9.17	12.61	12.09
Moisture Content (%)	23.8	24.7	25.5	26.6	27.2	19.4	19.0

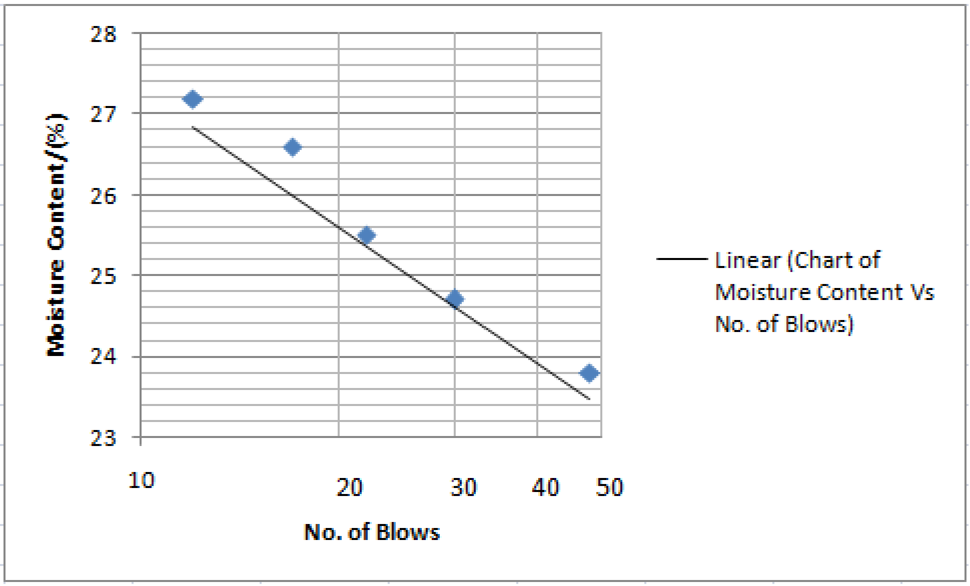


Figure A4.2 Graph for no. of blows Vs. moisture content of Sample 3

From figure A4.2,

Liquid Limit = 25%

Table A4.4 Table for Plastic Limit of Sample 3

Sample No.	6	7
Moisture content	19.4	19.0
Plastic Limit (PL)	19	

Plasticity Index = 6

A4.3 Atterberg Limit Test for Soil

Table A4.5 Reading of Atterberg Limit Test of soil sample

	Liquid Limit Test					Plastic Limit Test	
Sample No.	1	2	3	4	5	6	7
Number of Blows	37	31	22	17	10		
Wt. of dish /(g)	17.41	15.03	16.35	14.86	18.02	20.33	20.37
Wt. of wet soil and dish /(g)	29.85	27.10	30.48	28.55	33.86	34.16	34.35
Wt. of dry soil and dish/(g)	27.13	24.40	27.18	25.22	29.84	31.88	32.05
Wt. of water/(g)	2.72	2.70	3.3	3.33	4.02	2.28	2.3
Wt. of dry soil/(g)	9.72	9.37	10.83	10.36	11.82	11.55	11.68
Moisture Content (%)	28.0	28.8	30.5	32.1	34.0	19.7	19.7

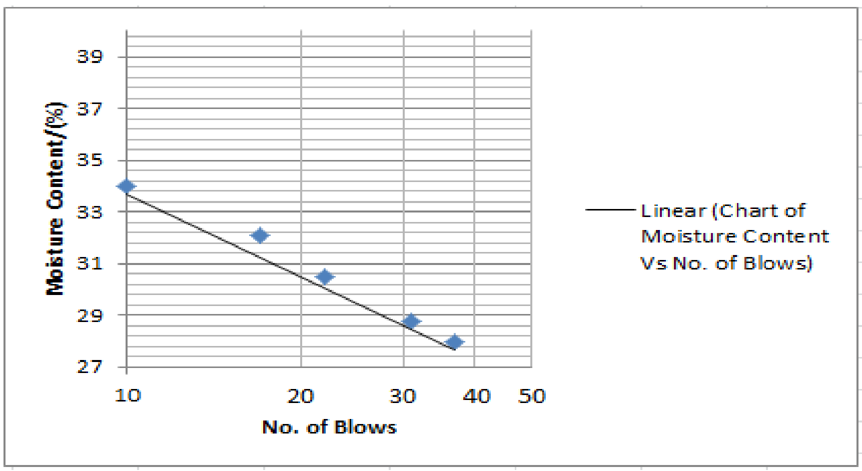


Figure A4.3 Graph for no. of blows Vs. moisture content of Soil

From figure A4.3,

Liquid Limit = 30%

Table A4.6 Table for Plastic Limit of Soil

Sample No.	6	7
Moisture content	19.7	19.7
Plastic Limit (PL)	20	

Plasticity Index = 10%

Appendix 5

Observations and Calculation of Modified Compaction Test

A5.1 Modified Compaction Test For Sample 2

Table A5.1 Reading of Modified Compaction Test of Sample 2

Test No.	**1**	**2**	**3**	**4**
Wt. of mould + wet soil/(g)	10054	10384	10586	10473
Wt. of mould/(g)	5625	5625	5625	5625
Wt. of wet soil/(g)	4429	4759	4961	4848
Wet density	1.92	2.06	2.15	2.10

Test No.	**1**	**2**	**3**	**4**
Wt. of dish/(g)	35.9	31.7	32.5	35.7
Wt. of dish + wet soil/(g)	503.1	391.4	347.3	411.1
Wt. of dish + dry soil/(g)	483.9	370.9	324.4	379.1
Wt. of water/(g)	19.2	20.5	22.9	32.0
Wt. of dry soil/(g)	448	339.2	291.9	343.4
Moisture content	4.3	6.0	7.8	9.3
Dry density	1.84	1.95	2.0	1.92

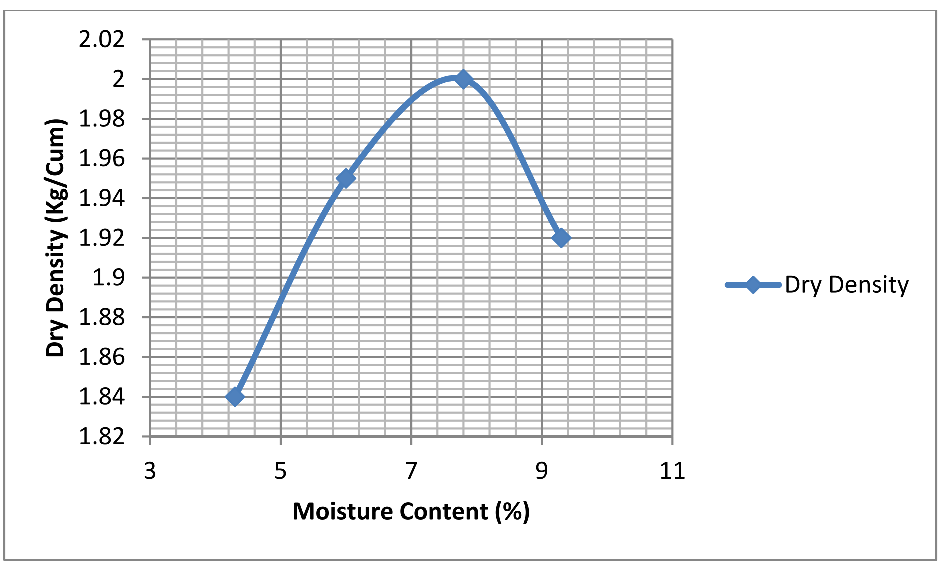


Figure A5.1 Graph for moisture content Vs. dry density of Sample 2.

From figure A5.1,

Maximum dry density = 2000 kg/m^3

Optimum moisture content = 7.8%

A5.2 Modified Compaction Test For Sample 3

Table A5.2 Reading of Modified Compaction Test of Sample 3

Test No.	**1**	**2**	**3**	**4**
Wt. of mould + wet soil/(g)	10192	10382	10645	10620
Wt. of mould/(g)	5625	5625	5625	5625
Wt. of wet soil/(g)	4567	4757	5020	4995
Wet density	1.98	2.06	2.18	2.17

Test No.	**1**	**2**	**3**	**4**
Wt. of dish/(g)	23.6	32.4	37.9	32.2
Wt. of dish + wet soil/(g)	347.3	377.6	381.3	417.1
Wt. of dish + dry soil/(g)	333.1	358.2	356.6	384.6
Wt. of water/(g)	14.2	19.4	24.7	32.5
Wt. of dry soil/(g)	309.5	325.8	318.7	352.4
Moisture content	4.6	6.0	7.8	9.2
Dry density	1.89	1.95	2.02	1.98

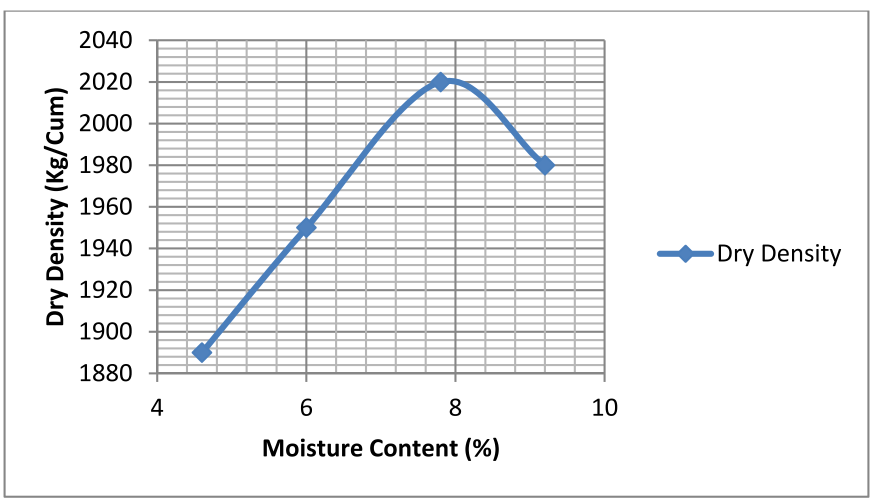


Figure A5.2 Graph for moisture content Vs. dry density of Sample 3.

From figure A5.2,

Maximum dry density = 2020 kg/m^3

Optimum moisture content = 8.0%

A5.3 Modified Compaction Test for Soil

Table A5.3 Reading of Modified Compaction Test of Soil

Test No.	**1**	**2**	**3**	**4**
Wt. of mould + wet soil/(g)	10346	10584	10836	10742
Wt. of mould/(g)	5557	5557	5557	5557
Wt. of wet soil/(g)	4789	5027	5279	5185
Wet density	2.08	2.18	2.29	2.25

Test No.	**1**	**2**	**3**	**4**
Wt. of dish/(g)	452.8	347.2	263.1	343
Wt. of dish + wet soil/(g)	434.7	328.4	245.8	317.2
Wt. of dish + dry soil/(g)	37.8	23.4	25.6	40.5
Wt. of water/(g)	18.1	18.8	17.3	25.8
Wt. of dry soil/(g)	396.9	305	220.2	276.7
Moisture content	4.6	6.2	7.9	9.3
Dry density	1.99	2.05	2.12	2.06

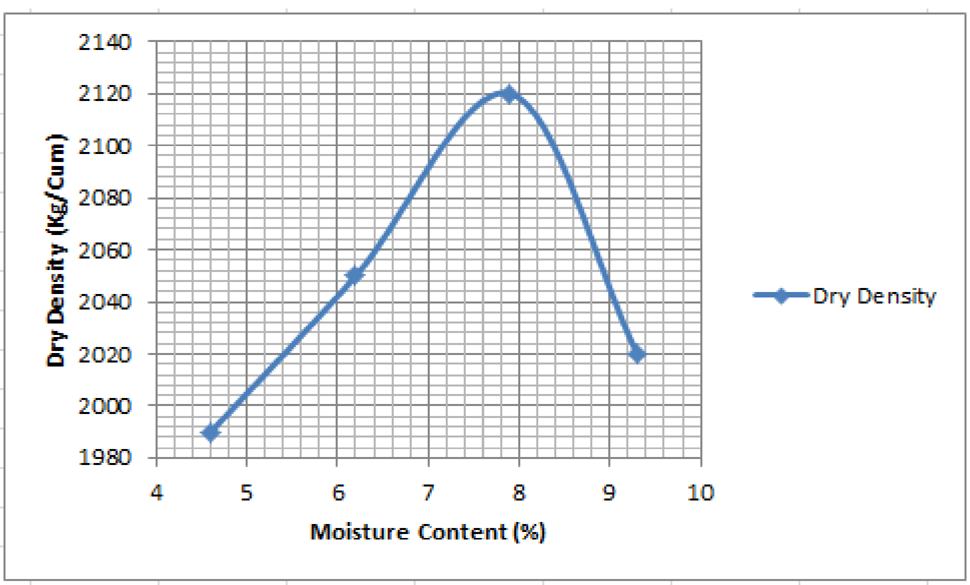


Figure A5.3 Graph for moisture content Vs. dry density of Soil.

From figure A5.3,

Maximum dry density	= 2120 kg/m^3
Optimum moisture content	= 7.9%

Appendix 6

Observations and Calculation of California Bearing Ratio Test

A6.1 California Bearing Ratio Test for Sample 2

Table A6.1 Reading of California Bearing Ratio Test of Sample 2

Penetration /(mm)	Load Dial Readings		Ring Factor (kN/Div)	Load /(kN)	
	Top	Bottom		Top	Bottom
0.00	0	0	0.025	0.000	0.000
0.25	13	14	0.025	0.325	0.350
0.50	48	47	0.025	1.200	1.175
0.75	145	110	0.025	3.625	2.750
1.00	268	210	0.025	6.700	5.250
1.25	375	340	0.025	9.375	8.500
1.50	463	482	0.025	11.575	12.050
1.75	538	588	0.025	13.450	14.700
2.00	605	665	0.025	15.125	16.625
2.25	657	730	0.025	16.425	18.250
2.50	700	785	0.025	17.500	19.625
2.75	745	830	0.025	18.625	20.750
3.00	785	872	0.025	19.625	21.800
3.25	818	912	0.025	20.450	22.800
3.50	848	946	0.025	21.200	23.650
3.75	878	975	0.025	21.950	24.375
4.00	902	998	0.025	22.550	24.950
4.25	925	1022	0.025	23.125	25.550
4.50	948	1048	0.025	23.700	26.200
4.75	975	1073	0.025	24.375	26.825
5.00	992	1096	0.025	24.800	27.400
5.25	1011	1116	0.025	25.275	27.900
5.50	1028	1138	0.025	25.700	28.450
5.75	1045	1159	0.025	26.125	28.975
6.00	1063	1181	0.025	26.575	29.525

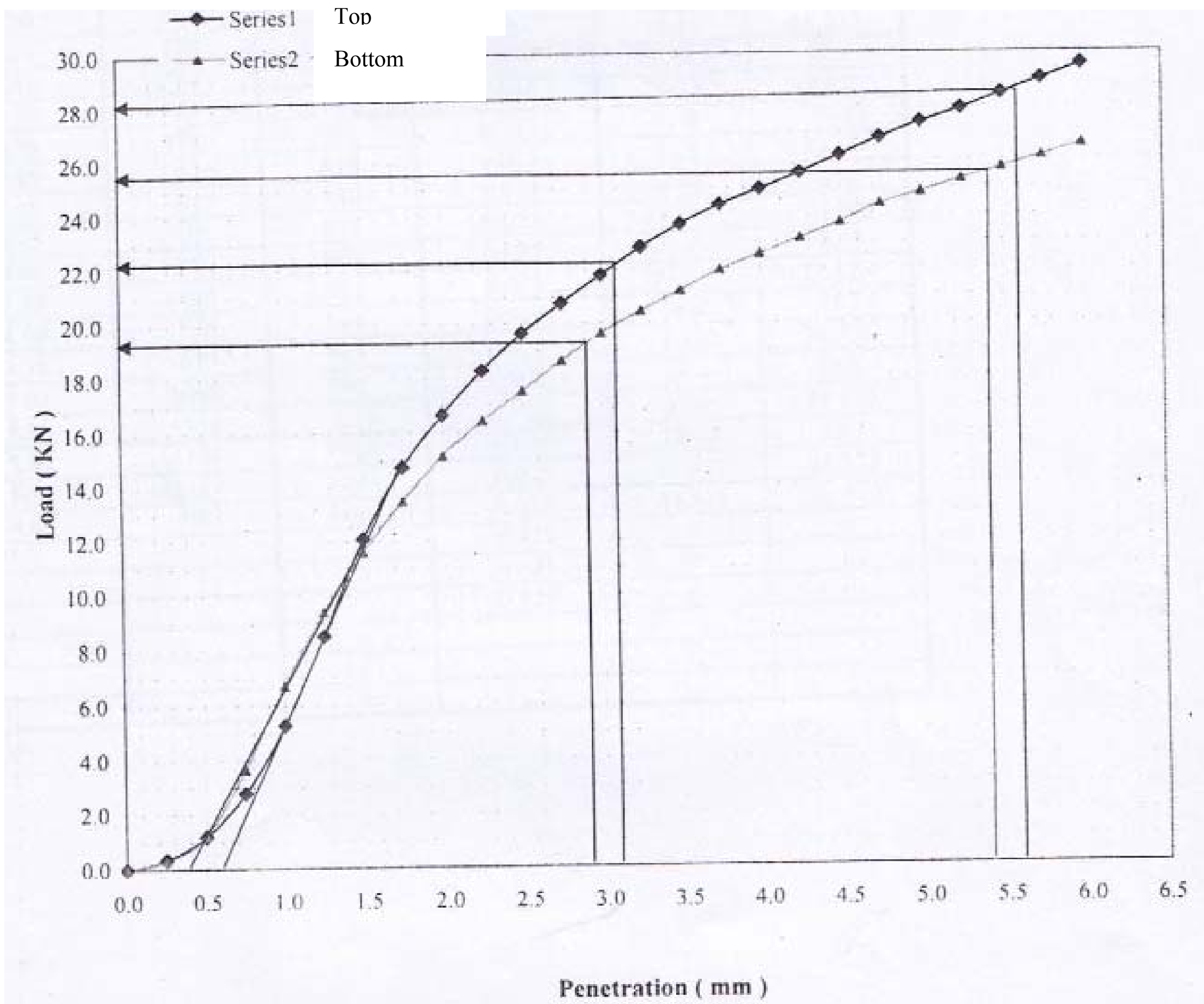


Figure A6.1 - Graph of Penetration Vs Load for Sample 2

Table A6.2 Results of California Bearing Ratio Test of Sample 2

	Top		Bottom	
	Load	CBR	Load	CBR
CBR at 2.5 mm penetration	19.2	145	22.2	168
CBR at 5.0 mm penetration	25.6	128	28.2	141
Accepted CBR	130			

A6.2 California Bearing Ratio Test for Sample 3

Table A6.3 Reading of California Bearing Ratio Test of Sample 3

Penetration	**Load Dial Readings**		**Ring Factor**	**Load /(kN)**	
/(mm)	**Top**	**Bottom**	**(kN/Div)**	**Top**	**Bottom**
0.00	0	0	0.025	0.000	0.000
0.25	8	18	0.025	0.200	0.450
0.50	27	77	0.025	0.675	1.925
0.75	48	140	0.025	1.200	3.500
1.00	81	190	0.025	2.025	4.750
1.25	112	225	0.025	2.800	5.625
1.50	136	252	0.025	3.400	6.300
1.75	158	273	0.025	3.950	6.825
2.00	175	293	0.025	4.375	7.325
2.25	188	311	0.025	4.700	7.775
2.50	199	328	0.025	4.975	8.200
2.75	209	345	0.025	5.225	8.625
3.00	218	360	0.025	5.450	9.000
3.25	225	378	0.025	5.625	9.450
3.50	233	397	0.025	5.825	9.925
3.75	241	414	0.025	6.025	10.350
4.00	243	431	0.025	6.075	10.775
4.25	252	447	0.025	6.300	11.175
4.50	259	466	0.025	6.475	11.650
4.75	265	488	0.025	6.625	12.200
5.00	271	505	0.025	6.775	12.625
5.25	275	523	0.025	6.875	13.075
5.50	283	539	0.025	7.075	13.475

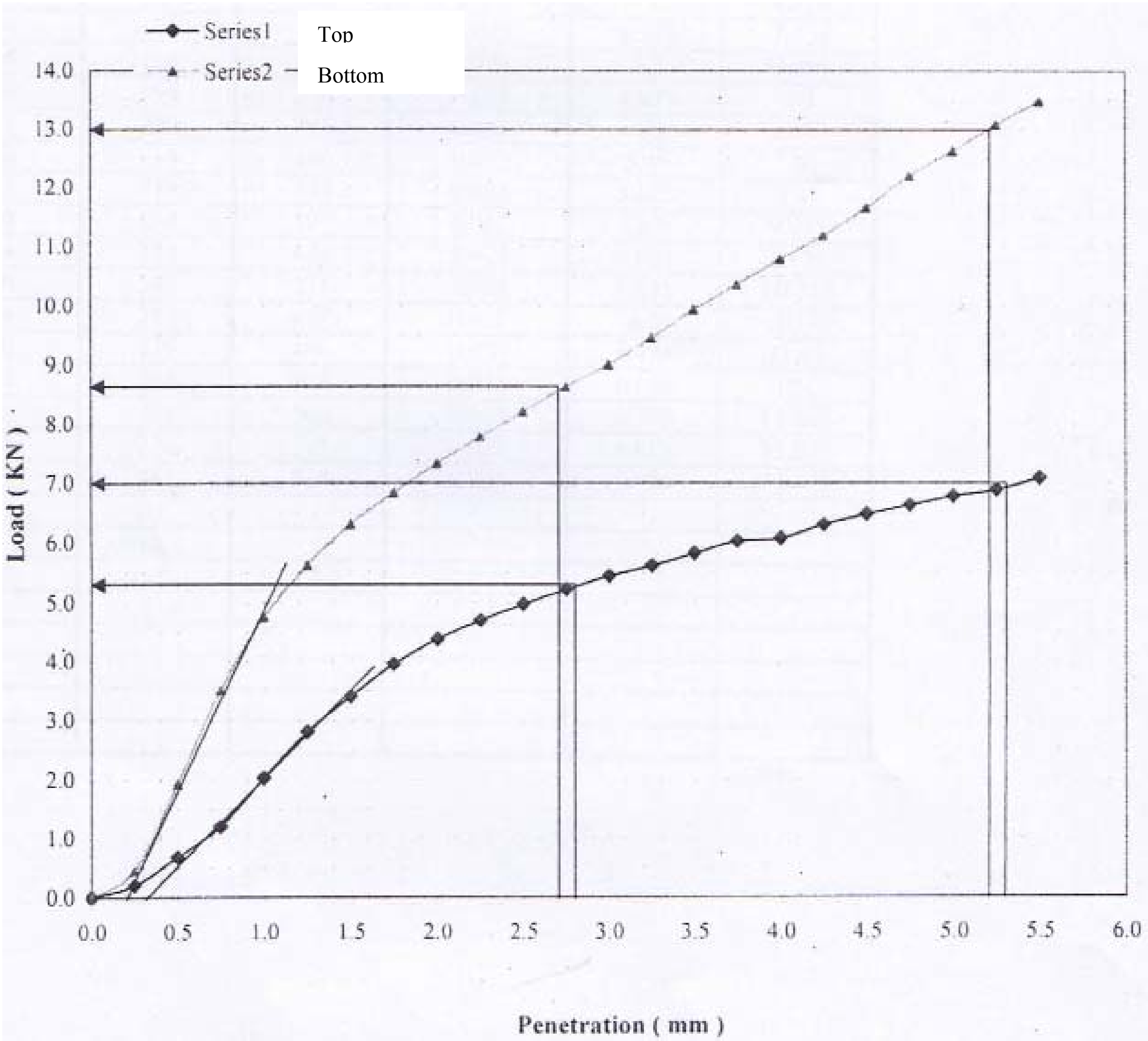


Figure A6.2 - Graph of Penetration Vs Load for Mix A, concrete debris (Sample 3)

Table A6.4 Results of California Bearing Ratio Test of Sample 3

	Top		Bottom	
	Load	CBR	Load	CBR
CBR at 2.5 mm penetration	5.3	40	8.6	65
CBR at 5.0 mm penetration	7.0	35	13.0	65
Accepted CBR	65			

A6.3 California Bearing Ratio Test for Soil

Table A6.5 Reading of California Bearing Ratio Test of Soil

Penetration	**Load Dial Readings**		**Ring Factor**	**Load /(kN)**	
/(mm)	**Top**	**Bottom**	**(kN/Div)**	**Top**	**Bottom**
0.00	0	0	0.025	0.000	0.000
0.25	6	9	0.025	0.150	0.225
0.50	16	25	0.025	0.400	0.625
0.75	31	47	0.025	0.775	1.175
1.00	52	72	0.025	1.300	1.800
1.25	78	102	0.025	1.950	2.550
1.50	108	134	0.025	2.700	3.350
1.75	137	165	0.025	3.425	4.125
2.00	163	192	0.025	4.075	4.800
2.25	186	216	0.025	4.650	5.400
2.50	205	243	0.025	5.125	6.075
2.75	219	280	0.025	5.475	7.000
3.00	230	305	0.025	5.750	7.625
3.25	240	320	0.025	6.000	8.000
3.50	255	338	0.025	6.375	8.450
3.75	264	358	0.025	6.600	8.950
4.00	272	375	0.025	6.800	9.375
4.25	278	392	0.025	6.950	9.800
4.50	284	408	0.025	7.100	10.200
4.75	292	420	0.025	7.300	10.500
5.00	298	435	0.025	7.450	10.875
5.25	304	452	0.025	7.600	11.300
5.50	308	466	0.025	7.700	11.650
5.75	313	478	0.025	7.825	11.950

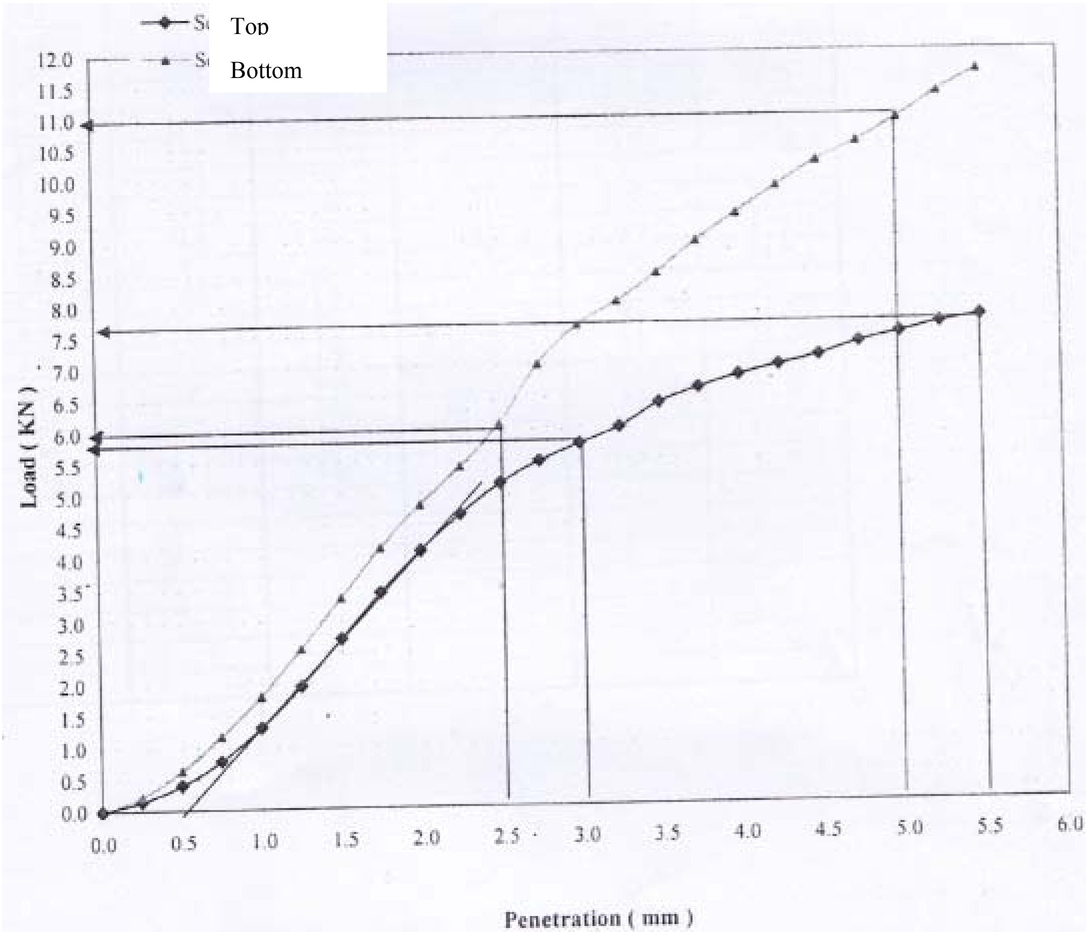


Figure A6.3 - Graph of Penetration Vs Load for soil

Table A6.6 Results of California Bearing Ratio Test of Soil

	Top		Bottom	
	Load	CBR	Load	CBR
CBR at 2.5 mm penetration	5.7	43	6.0	45
CBR at 5.0 mm penetration	7.6	38	11.0	55
Accepted CBR	50			

A6.4 California Bearing Ratio Test for RR Masonry Debris

Table A6.7 Reading of California Bearing Ratio Test of RR masonry Debris

Penetration	Load Dial Readings		Ring Factor	Load /(kN)	Load /(kN)
/(mm)	Top	Bottom	(kN/Div)	Top	Bottom
0.00	0	0	0.025	0.000	0.000
0.25	52	55	0.025	1.300	1.375
0.50	103	115	0.025	2.575	2.875
0.75	152	161	0.025	3.800	4.025
1.00	193	202	0.025	4.825	5.050
1.25	225	236	0.025	5.625	5.900
1.50	270	282	0.025	6.750	7.050
1.75	305	315	0.025	7.625	7.875
2.00	346	356	0.025	8.650	8.900
2.25	386	402	0.025	9.650	10.050
2.50	425	445	0.025	10.625	11.125
2.75	456	477	0.025	11.400	11.925
3.00	488	502	0.025	12.200	12.550
3.25	515	532	0.025	12.875	13.300
3.50	536	552	0.025	13.400	13.800
3.75	555	576	0.025	13.875	14.400
4.00	581	591	0.025	14.525	14.775
4.25	602	616	0.025	15.050	15.400
4.50	623	636	0.025	15.575	15.900
4.75	646	657	0.025	16.150	16.425
5.00	671	673	0.025	16.775	16.825
5.25	692	695	0.025	17.300	17.375
5.50	712	716	0.025	17.800	17.900
5.75	732	735	0.025	18.300	18.375
6.00	752	762	0.025	18.800	19.050

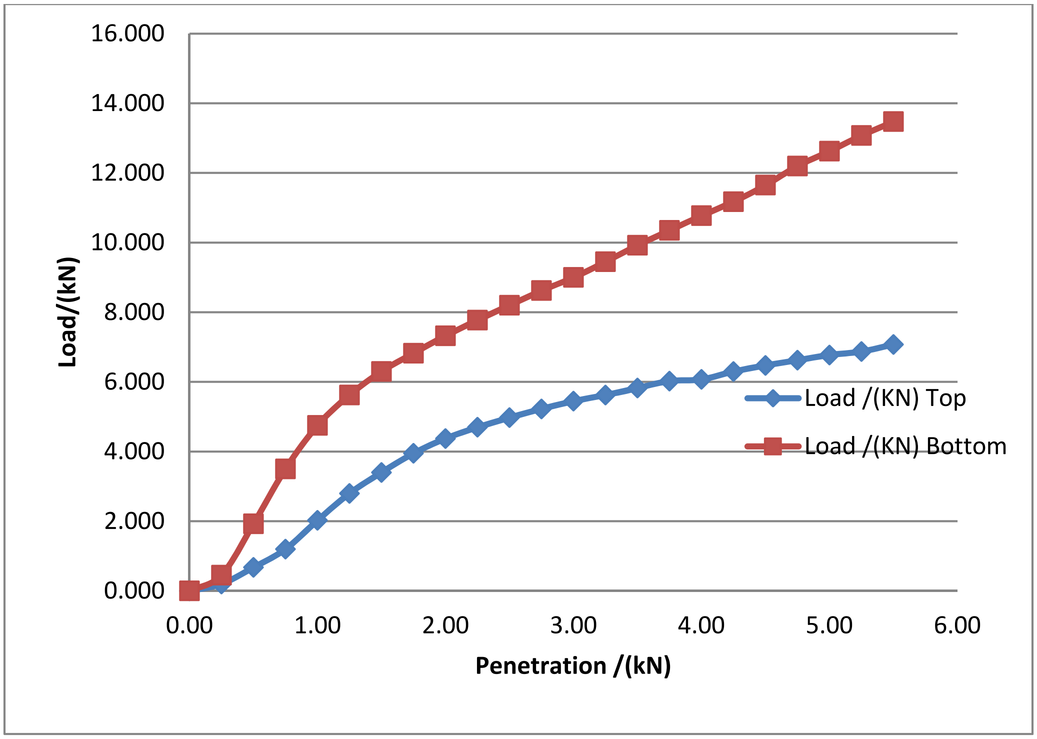


Figure A6.4 Graph of Penetration Vs Load for RR Masonry debris

Table A6.8 Results of California Bearing Ratio Test of Random Rubble Masonry Debris

	Top		Bottom	
	Load	CBR	Load	CBR
CBR at 2.5 mm penetration	10.92	82	11.43	86
CBR at 5.0 mm penetration	17.24	86	17.30	86
Average CBR	86			

Appendix 7

Fig. A7. 1 (a) Construction Debris

Fig A7.1 (b) Construction Debris

Fig. A7. 2 Concrete Debris

Fig. A7.3 Random Rubble Masonry Debris (Lime Stone)

Fig. A7.4 Cement Plaster Debris

Fig A7.5 Concrete Block Wall

Fig A7.6 Lime Stone