The Islamic University of Gaza
High Studies Deanery
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Civil Engineering Department
Infrastructure Engineering Master Program

USE OF RECLAIMED ASPHALT PAVEMENT AND DEMOLITION DEBRIS IN ROAD PAVEMENT BASE LAYERS

استخدام ركام الإسفلت ومخلفات الهدم في طبقات الأساس لرصف الطرق

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بِسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ

((وَجَعَلْنَا بَيْنَهُمْ وَبَيْنَ الْقُرَى الَّتِي بَارَكْنَا فِيهَا قُرًى ظَاهِرَةً وَقَدَّرْنَا فِيهَا السَّيْرَ سِيرُوا فِيهَا لَيَالِيَ وَأَيَّاماً آمِنِينَ)) (سبأ 18)

DEDICATION

To My Parents, Wife, Sons, Brothers and Sisters

Acknowledgments

I would like to send my sincere appreciation to people who made this thesis possible. Special thanks are to my supervisor Prof. Dr. Shafik Jendia, for his guidance, patience and encouragement.

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Moreover, I am also very thankful to my wife for supporting me during my study.

Abstract

Using recycled material in different application means reducing costs in addition to saving environment. This research study the using of two different recycling materials which are available in Gaza with huge quantities due to political situation and construction development. These materials area demolition debris and reclaimed asphalt pavement. Many researches studied using demolition debris as base coarse aggregates, but this research added reclaimed asphalt pavement to demolition debris and for comparison to conventional aggregates in different ratios 10%, 20%, 30%, 40% and 50%. For studying the properties of these mixtures, Sieve analysis, Specific gravity and absorption, Atterberg limits, Los Angeles abrasion test, Sand equivalent, Proctor compaction, California bearing ratio, and Bitumen extraction of reclaimed asphalt pavement were performed. Results showed that some properties is improved with adding reclaimed asphalt pavement as Los Angeles value, Sand equivalent and Absorption, but other properties decreased specially California bearing ratio. Sieve analysis illustrates that particles with gradation greater than 50mm have to be removed from reclaimed asphalt pavement.

It is recommended that the maximum content of reclaimed asphalt pavement in demolition debris must not be greater than 40%. But 50% content of reclaimed asphalt pavement in conventional material is valid for Gaza strip condition.

الملخص

استخدام المواد المعاد تدويرها في التطبيقات المختلفة له مردوده من حيث خفض التكاليف وحماية البيئة، هذا البحث يعنى بدراسة مادتين من المواد المعاد تدويرها والتي تتوفر في قطاع غزة بكميات كبيرة نظراً للوضع السياسي وكذلك التنمية العمرانية وهما ناتج الهدم وركام الإسفلت. العديد من الدراسات التي درست استخدام ناتج الهدم كطبقة بيس كورس، ولكن هذا البحث يدرس اضافة الخليط الاسفلتي المعاد استخدامه إلى ناتج الردم، وكذلك للمقارنة تم إضافته إلى الحصويات الطبيعية المعتاد استخدامها في طبقات الاساس وذلك بنسب مختلفة 10%,20%,30%,40%,50% ، وقد تم دراسة خصائص هذه الخلائط المختلفة، حيث اجريت الاختبارات التالية: التحليل المنخلي والوزن النوعي والامتصاص وحدود اتربيرج وفحص لوس أنجيلوس للتآكل والمكافئ الرملي وكذلك دمك بروكتور وفحص تحمل كاليفورنيا بالاضافة الى فحص نسبة البيتومين في الخليط الاسفلتي المعاد استخدامه.

وقد أظهرت النتائج حدوث تحسن في بعض الخصائص بعد اضافة الخليط الاسفلتي المعاد استخدامه مثل قيمة تآكل لوس أنجيلوس والامتصاص وكذلك المكافئ الرملي في حين أن بعض الخصائص تأثرت سلباً وخصوصاً في تحمل كاليفورنيا، كما أن تحليل المناخل قد أظهر ضرورة ازالة الحصويات ذات تدرج أكبر من 50 ملم من الخليط الاسفلتي المعاد استخدامه قبل اضافته.

وخلصت الدراسة بأنه بالإمكان اضافة نسبة 50% من الخليط الاسفلتي المعاد استخدامه في حالة الحصويات الطبيعية المعتاد استخدامها في طبقات الاساس، ونسبة لا تتجاوز 40% من الخليط الاسفلتي المعاد استخدامه في حصويات ناتج الهدم.

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List of Abbreviation:

AASHTO	American Association of State Highway and Transportation
Official	
ASTM	American Society for Testing Materials
MPWH	Ministry of Public Work and Housing
CBR	California Bearing Ratio
SSD	Saturated Surface Dry condition
C.A	Conventional Aggregates
D.D	Demolition Debris
RAP	Reclaimed Asphalt Pavement
RCA	Recycled concrete aggregates
DOT	U.S department of Transportation
MSL	Material and Soil Labs
R/C	Reclaimed asphalt pavement / Conventional material
R/D	Reclaimed asphalt pavement / Demolition debris
LL	Liquid limit
P.L	Plastic limit
PI	Plasticity index
S.G	Specific gravity

Chapter One: Introduction

1.1 Background

Gaza strip is a coastline which consider one of the most density area of population with an area of 365 km^2 and the population about 1.763 million inhabitants. Gaza strip is considered land of wars, as Israeli attacks are repeated from time to another, this small area exposed to two wars in the last five years. Each war left thousands of demolition debris and destroyed several roads which became in need to rehabilitation or reconstruction and so removing asphalt layers with huge quantities.

This research deals with two types of material which are available in huge quantities and make bad environmental impact on people. These materials are demolition debris and reclaimed asphalt pavement, which exist normally over all the word as a result of rabid development of construction techniques. In Gaza, repeated Israeli attacks causes additional quantities of demolition debris.

In addition to lack of materials that enter to Gaza because of siege. There is great need to accomplish many researches in the field of recycling material to make use of these quantities, save environment, meet required material in local market, make solutions for structural problems due to non-scientific application of recycling material and decrease the amount of space needed to store the thousands of tons of these materials created each year.

Many researches [1, 2, 3, 4] over the world studied using reclaimed asphalt in hot mix asphalt and as a base course. Other researches [5, 6, 7, 8] made use of demolition debris in concrete mix and as base course layer too. But the use of reclaimed asphalt and demolition debris mix as a base layer still need scientific studies to determine its properties and preparing new specifications.

Using reclaimed asphalt with conventional aggregate is a practical application and many professionals within the pavement industry support that 50 percent is an optimum reclaimed asphalt pavement, a published study support this and suggested 60% ratio as maximum limit [3].

1.2 Problem Statement

Examining additional applications of recycling material will make wide alternatives to save money and improve environmental conditions. Local situation with huge quantities of demolition debris, which is about 117500 tons from 2009 and 2012 wars on Gaza. Reclaimed asphalt pavement of about 35000 tons from reconstruction just three streets in Gaza (See chapter 4 for more details) forces researchers to deal with these materials and test its properties.

Using a mix contains reclaimed asphalt pavement (RAP) and demolition debris requires new specifications and testing procedures. Many researches on using RAP with conventional aggregate made tests and studied the properties of reclaimed asphalt with contents of 0, 25, 50, 75, and 100 percent mixed with conventional aggregate and they supported 50%. This research will take into consideration contents of 0, 10, 20 ,30 ,40 and 50% of RAP (by weight) in conventional aggregates, in addition to using a mix of RAP with demolition debris with same rates.

1.3 Importance of The Study

1. Preservation of the existed raw materials and natural resources.
2. Reducing the amount of waste and the area of land used for landfill.
3. Saving environment.
4. Reducing problems which is caused by non-scientific applications of recycling material.

1.4 Research Limitations

The results of this research depend on set of limitations and criteria, these limitations are as follow:

1. The source of demolition debris is unknown, therefore it is difficult to predict the existence of plaster, tiles or block debris. In the same way the amount and composition of asphalt cement in the reclaimed asphalt pavement are both unknown. So this research deals with local debris and all results will be valid for tested material.

2. In general local crusher produce aggregates suitable to concrete and block factories (small gradation), but after serious research, it's found that "Kuhail crusher" works in producing aggregate for base layers (large gradation).

1.5 Research Aim and Objectives

The main aim of this research is to study the properties of using reclaimed asphalt pavement and demolition debris in road pavement base layers. The objectives of this study are:

1. To examine if RAP content up to 50% with conventional aggregates is applicable in Gaza strip conditions.
2. To Identify the properties of reclaimed asphalt pavement mix with demolition debris as base layer.
3. To determine the maximum ratio of reclaimed asphalt pavement to demolition debris.

1.6 Methodology

Studding using reclaimed asphalt pavement and demolition debris mixed with conventional base course required preparing work program. Figure 1.1 illustrate main steps to achieve the objectives of this research. This means that the following tasks will be executed:

1. Conducting a literature review about reclaimed asphalt pavement, conventional aggregate and demolition debris as aggregate.
2. Site visits and investigations of the aggregate production plants to get more information and to collect samples.
3. Adding RAP to conventional aggregates with rates of 0, 10, 20, 30 ,40 and 50% ratios. Performing tests as sieve analysis (AASHTO-T 27), specific gravity and absorption (AASHTO-T 84), Los Angeles abrasion test (AASHTO-T 96), Proctor compaction test (AASHTO- T 180), CBR (AASHTO- T193), Sand equivalent and atterberg limits.

4. Adding RAP to demolition debris with the same ratios and performing tests
5. Comparing results with conventional aggregate properties.
6. Drawing conclusions and recommendations.

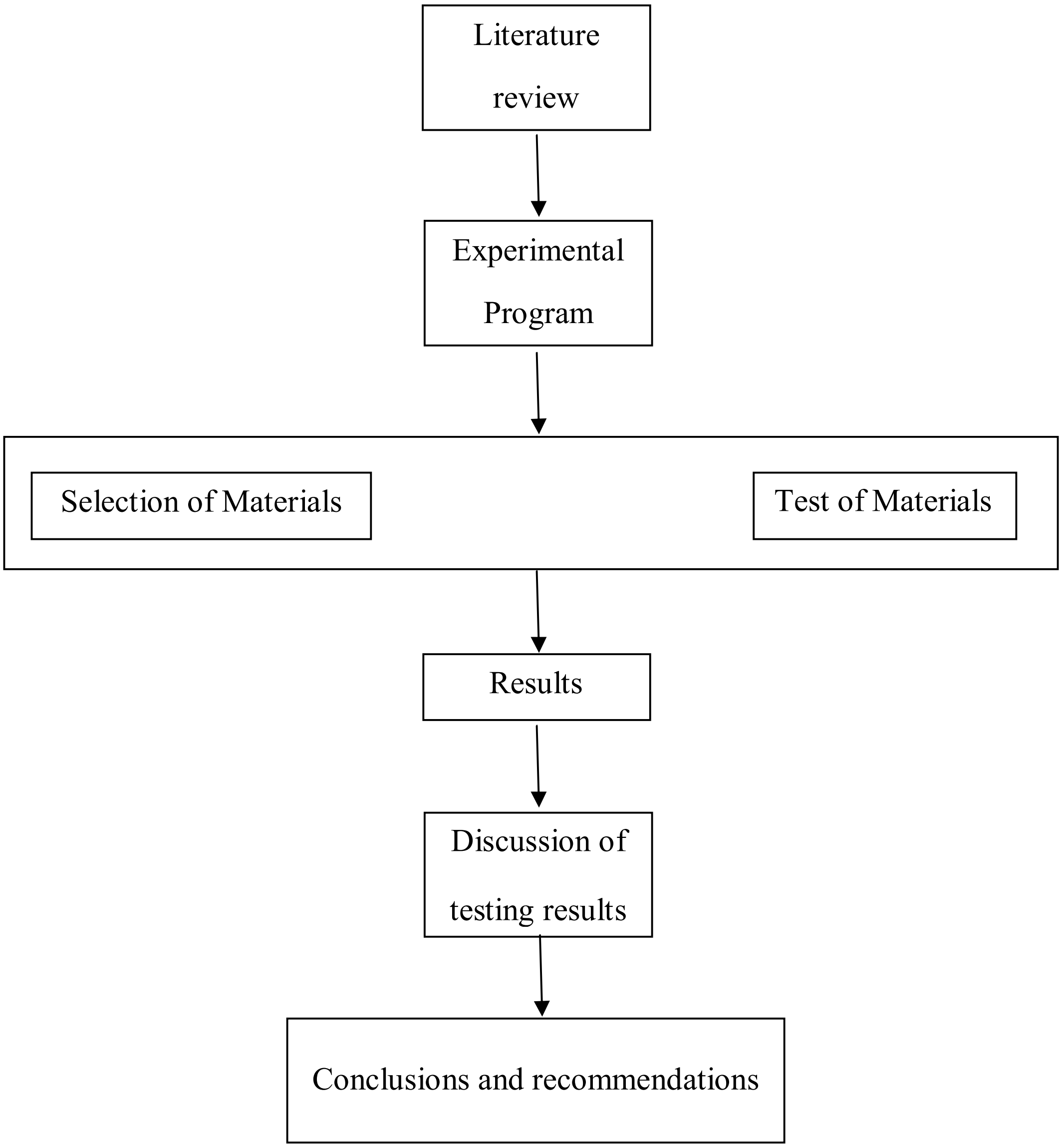

Figure 1.1 Work plan chart

1.7 Thesis Outline

The thesis consists of 7 chapters. Chapter one presents the introduction, and chapter 2 about literature review for the applications of recycling material. The specifications of base course materials is discussed in chapter three. Chapter four presents studied materials and chapter five illustrates used materials and testing program. Chapter six provides the test results. Conclusions and recommendations is given in chapter seven.

Chapter Two: Literature Review

2.1 Introduction

Many researches studied recycling demolition debris as a base course material and others studied using reclaimed asphalt pavement with various rations with conventional aggregate. But this thesis deals with a capitation of these research and study the use of demolition debris and reclaimed asphalt pavement as base course material. So in this chapter some of these researches will be reviewed.

2.2 RAP as Base Layer

McGarrah [1] discussed eight studies of using reclaimed asphalt pavement and conventional aggregate. These studies from different countries, tested both similar and different types of engineering properties. In addition, the studies analyzed different types of reclaimed asphalt pavement, at different blends, with different types of conventional aggregate. So by comparing similar tests result from all 8 studies with conventional aggregates, some general trends appear.

Table 2.1: Comparing results of eight studies of using reclaimed asphalt pavement and conventional materials [1]

Report	Blended 1	Dry Density	Moisture Content	Permeability	CBR	Resilient Modulus
Cooley (2005)	Yes	Decreased	Decreased	---	Decreased	---
Garg & Thompson (1996)	No	Decreased	Increased	---	Decreased	---
MacGregor (1999)	Yes	---	---	No Change	---	Increased
Bennert & Maher (2005)	Yes	Decreased	Decreased	Decreased	---	Increased
Papp (1998)	Yes	Decreased	Decreased	---	---	Increased
Sayed (1993)	No	---	Decreased	---	Decreased	---
Taha (1999)	Yes	Decreased	No Change	Increased	Decreased	---
Trzebiatowski (2005)	No	Decreased	---	Increased	---	---

1. Details whether the RAP material was blended with conventional aggregate.

McGarrah [1] contacted with state material engineers to determine the current practice of the united state department of transportation (DOT) regarding the use of reclaimed asphalt pavement as a base course material. Table (2.2) shows a survey of the practices of department of transportation (DOT) regarding the use of RAP as a base course material.

Table 2.2: Department of transportation survey of reclaimed asphalt pavement use as a base course material [1]

State	Rap Allowed[1]	Max %	Processed	Testing
Florida	No	---	---	---
Illinois	No	---	---	---
Montana	Yes	50-60%	No	Corrected Nuclear Gauge
New Jersey	Yes	50%	Yes - Gradation	Corrected Nuc. Gauge + Sample
Minnesota	Yes	3%[2]	Yes - Gradation	Dynamic Cone Penetrometer
Colorado	Yes	50%	Yes - Max Agg. Size	Roller Compaction Strip
Utah	Yes	2%[2]	Yes - Gradation	Nuc. Gauge or Breakdown Curve
Texas[1]	Yes	20%	Unknown	Various (including Nuc. Gauge)
California[1]	Yes	50%	Unknown	No special testing procedure listed
New Mexico[1]	Yes	Unknown	Unknown	Corrected Nuc. Gauge
Rhode Island[1]	Yes	Unknown	Yes - Gradation	Unknown
South Dakota[1]	No	---	---	---

1 These states were not contacted and the information listed in the table is from the state's current standard specification.
2 Maximum bitumen content in the mix of RAP and conventional aggregates

Bennert and Maher [2], Tested recycled asphalt pavement (RAP) and recycled concrete aggregates (RCA) to evaluate their potential use as base and subbase materials. The testing of the RAP, RCA, and their blends with the base material, showed that as the % RAP increased in the blend, both the CBR value and permeability decreased. RAP also caused larger permanent deformations during the cyclic triaxial testing. The inclusion of RCA provided the largest CBR, largest resilient modulus, and lowest permanent deformation values. However, as the % RCA increased, the blend's permeability decreased.

Cooley [3], investigated RAP for use in full-depth-reclamation rehabilitation methods. Cooley conducted material classification and compaction tests. Then evaluated the strength, stiffness and moisture susceptibility on two sources of RAP blended with two types of conventional aggregate at RAP contents of 0, 25, 50, 75 and 100 %. The data indicate that CBR values decrease as RAP content increases, with the greatest percentage reduction occurring with the addition of 25 percent RAP. For stiffness testing at the optimum moisture content determined for each blend, the general trend was a decrease in stiffness from 0 percent RAP to 25 percent RAP, followed by a steady increase in stiffness as the RAP content was increased from 25 to 100 percent.

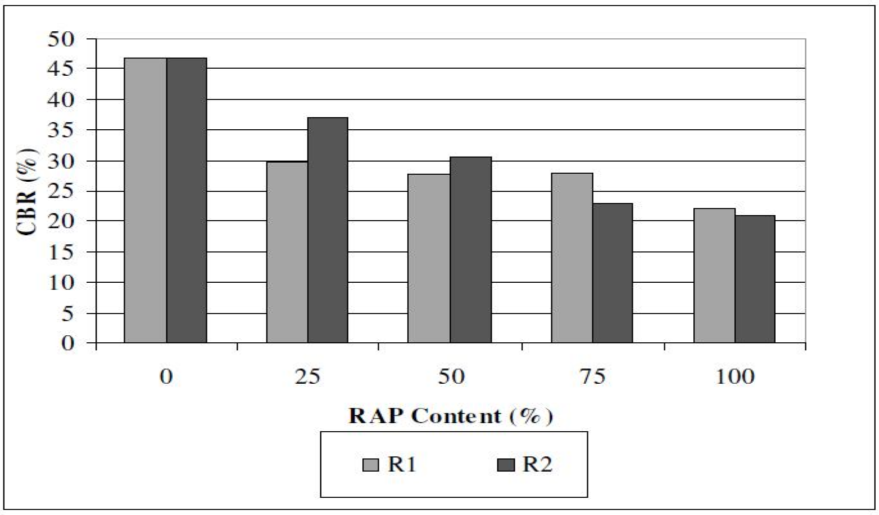

Figure 2.1 CBR for different reclaimed asphalt pavement content and type [3]

R1: Obtained from Utah Department of Transportation Interstate 84 (I-84) in Weber Canyon.

R2: Obtained from a parking lot pavement in Pleasant Grove, Utah.

2.3 Demolition Debris as Base Layer

Jendia and Besaiso [5], tested crushed building debris generated by UN-crusher. These debris resulted from Israeli aggression war 2009 on the Gaza Strip and testing results showed that the crushed material has a maximum Los Angles value of (40%). The structural layer coefficient according to the AASHTO at (CBR ≈ 176%) and at (degree of compaction of 100%) is larger than 0.14/in. This indicates that it has great value of bearing capacity. The results of the absorption test (approximately 5.0%) compared to AASHTO specifications (not greater than 3%). This is because the crushed material samples include more impurities. The value of soundness (11.4%) indicates that the sample is high durable and can resist bad weather conditions of freezing and thawing. According to AASHTO, the max. limit for soundness is 18%. The gradation of the crushed material will be improved by adding approximately 25 % fine material (lime stone) with a gradation of 0/4.75 mm to the crushed material. Table (2.3) shows properties of crushed building debris according to Jendia and Besaiso.

Table (2.3): Engineering properties of crushed building debris [5].

Technical Properties		**Specifications AASHTO**	**Test Results**
Los Angeles Abrasion		Max 45%	40%
CBR (100% compaction)		Min 80%	176%
Liquid Limit		Max 25%	17%
Plasticity Index		Max 6%	NP
Specific gravity (SSD) coarse		2.6	2.35 g/cm^3
Specific gravity (SSD) fine		2.6	2.52 g/cm^3
Specific gravity (OD) coarse		2.6	2.23 g/cm^3
Specific gravity (OD) fine		2.6	2.42 g/cm^3
Proctor	OMC		9.5%
	MDD (g/cm^3)		2.088 g/cm^3
Absorption % Coarse aggregate		Max 3%	5.33%
Absorption % Fine aggregate		Max 3%	4.38%
Soundness test		Max 17%	11.1%
Soil Classification			A-1-a

Raju et al [6] studied the use of recycled aggregate from building waste as base course and sub-base course. Different types of building waste have been collected from various sources such as Crushed concrete (fresh), Crushed concrete (20 years old), Stone masonry (fresh), Stone masonry (20 years old), Brick masonry and Conventional aggregate. Based on the experimental results obtained, crushed concrete can be effectively used as a road material in different layers, brick aggregate found to be relatively soft compared with other recycled aggregate and can be used as a sub-base material but not in base course and wearing course. Water absorption of all types of waste materials found to be high compared with conventional aggregate, except brick masonry, all other materials satisfying the specific gravity requirements. Los Angeles abrasion value for all materials found to be within the limits except brick.

2.4 Demolition Debris as an Asphalt Binder Course

Jendia and Qreaqa' [9], used aggregates result from crushing demolition building debris in asphalt mixture of an asphalt binder course in road pavement. To investigate the applicability of using the recycled aggregates, several tests were conducted, and Marshal samples with both recycled and conventional aggregates were prepared according to the specifications.

The results showed that it is possible to use the recycled aggregates in preparing the Asphalt Binder Course taking into account the need to increase the bitumen content (about 0.4%) more than the Asphalt binder course using the conventional aggregates (i.e. the optimum bitumen content using recycled aggregates is 5.7% and for conventional is 5.3%). However, the economic study in this research shows that using the recycled aggregate is feasible and has less cost than using the conventional one [9].

2.5 Conclusion

Several studies were conducted on using reclaimed asphalt with conventional aggregates as base course or asphalt binder course. Other studies deal with using demolition debris as aggregates for base course. Results recommended RAP content 50% with conventional aggregates in many countries. So this thesis will examine if 50% content of RAP with conventional aggregate is suitable for Gaza conditions. In other hand indicating the maximum RAP content with demolition debris aggregates which satisfy specifications.

Chapter Three: Base Course Specification

3.1 Background

It is essential to have standard specification to compare obtained results, there are many specifications overall the word. The most common is the American Association of State Highway and Transportation Officials (AASHTO) which is a standard setting body and publishes specifications, test protocols and guidelines which are used in highway design and construction throughout the United States. Despite its name, the association represents not only highways but air, rail, water, and public transportation as well.

Other specification which relates to highway standards is International formerly known as the American Society for Testing and Materials (ASTM). The Palestinian ministry of public work and housing established a local standard for civil engineering works.

3.2 Gradation Curves

3.2.1 AASHTO (2010) Specification [13]

AASHTO standards (2010) division 300 address base course specification, section 304 is about aggregate base course, in this section aggregate gradation is divided into seven classes. Base course gradation in Gaza is more conform to the fifth class which is named crushed stone (Fine). Table 3.1 shows the required gradation of base course material according to AASHTO standards. Table 3.2 presents ASTM standard gradation, and Table 3.3 according to German specification (0/56) gradation for crushed road base.

Table 3.1 Gradation of Base course materials AASHTO (2010) [13]

Item No.	304.1	304.2	304.3	304.33	304.4	304.5	304.6
Item	Sand	Gravel	Crushed Gravel	Crushed Aggregate For Shoulders	Crushed Stone (Fine)	Crushed Stone (Coarse	Crushed Stone (Very Coarse)
Sieve Size	Percent Passing By Weight						
6 in. (150 mm)	100	100	-	-	-	-	100
5 in (125 mm)	-	-	-	-	-	-	-
4 in (100 mm)	-	-	-	-	-	-	-
3 ½ in. (90 mm)	-	-	-	-	-	100	-
3 in. (75 mm)	-	-	100	-	-	85-100	60-90
2 ½ in. (63.5 mm)	-	-	-	-	-	-	-
2 in. (50 mm)	-	-	95-100	-	100	-	-
1 ½ in. (37.5 mm)	-	-	-	-	85-100	60-90	45-75
1 in (25.0 mm)	-	-	55-85	90-100	-	-	-
¾ in. (19.0 mm)	-	-	-	-	45-75	40-70	35-65
#4 (4.75 mm)	70-100	25-70	27-52	30-65	10-45	15-40	15-40
# 200 (0.075 mm) (In Sand Portion)	0-12	0-12	0-12	-	-	-	-
# 200 (0.075 mm) (In Total Sample)	-	-	-	0-10	0-5	0-5	0-5

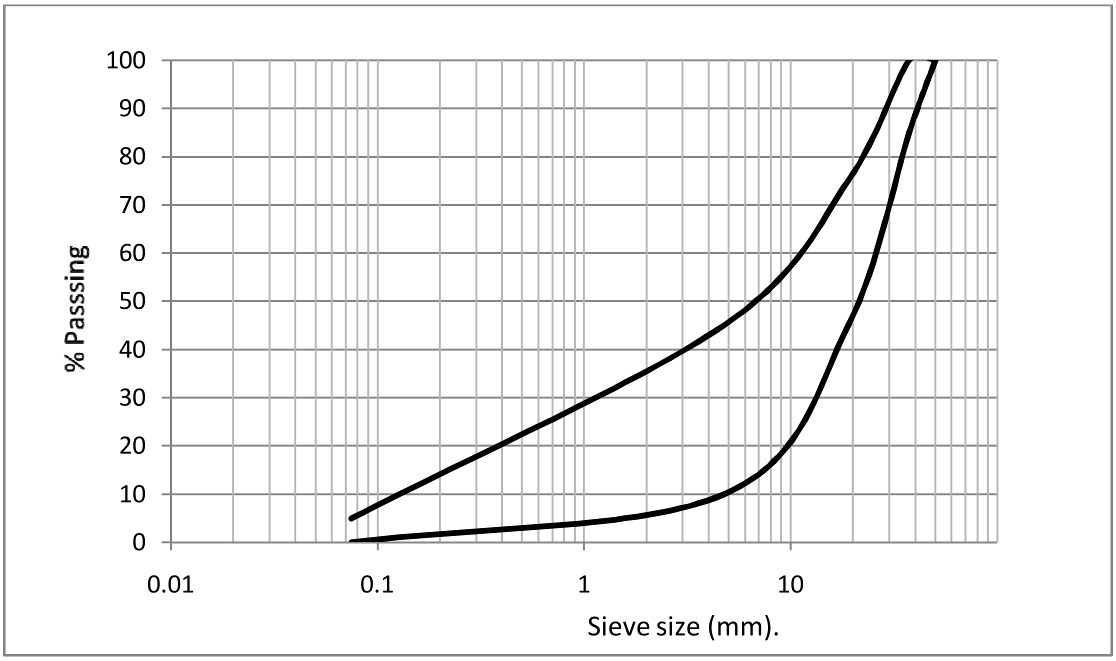

Figure 3.1 Gradation curve according to AASHTO (2010) Crushed stone fine

3.2.2 ASTM Specification [10]

American Society for Testing Materials ASTM designation D2940-74 specified gradation requirements for base and sub-base materials. Base course materials gradation is shown in table 3.2.

ASTM put other requirements for base materials as:

1. Coarse aggregate to be hard and durable.
2. Fraction passing the 0.075mm sieve not to be exceed 60% of the fraction passing the 0.6mm sieve.
3. Fraction passing the 0.425mm sieve shall have a liquid limit no greater than 25% and plasticity index not greater than 4%.

ASTM specification doesn't give a strength criterion for the compacted material. But the Asphalt institute thickness design manual requires a CBR value 80 percent for base materials.

Table 3.2 Gradation of base course materials according to ASTM [10]

Sieve Size	Grading percentage passing Bases
2 in. (50 mm)	100
1 ½ in. (37.5 mm)	95-100
¾ in. (19.0 mm)	70-92
3/8 in (9.5mm)	50-70
#4 (4.75 mm)	35-55
# 30 (600 µm)	12-25
# 200 (75 µm)	0-8

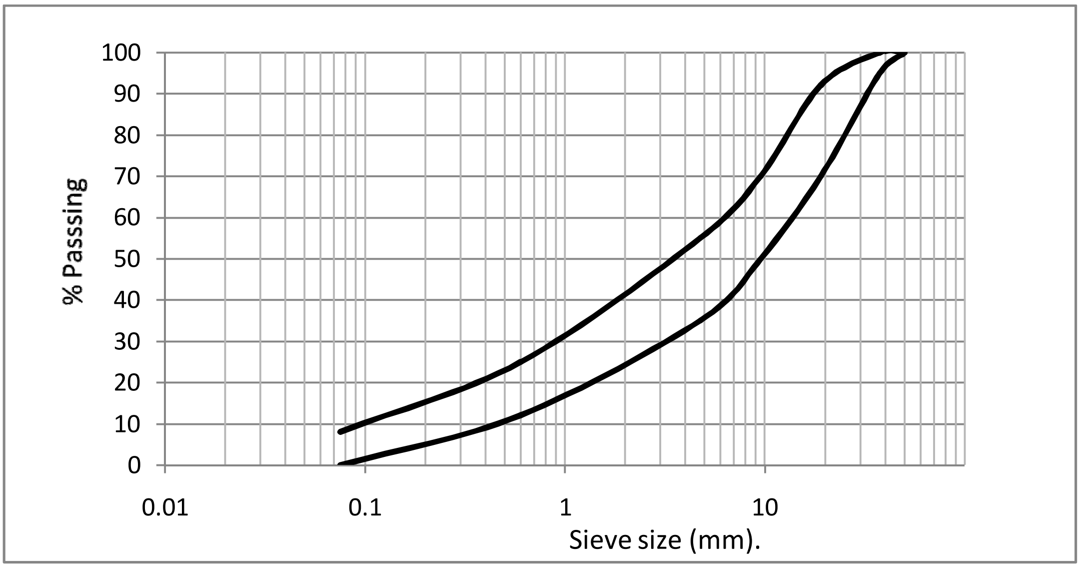

Figure 3.2 Gradation curve of base course according to ASTM [10]

3.2.3 German Specification [10]

German specification gives three aggregate gradation for base course materials, which are (0/32), (0/45) and (0/56). Base course materials gradation in Gaza is more conform to the third gradation (0/56), table 3.3 shows (0/56) gradation for crushed road base.

Table 3.3 (0/56) Gradation for crushed road base German specification [10]

Sieve Size (mm)	Grading percentage passing Bases
56	90 - 100
45	70 – 90
31.5	61 – 81
22.4	54 – 77
11	39 – 63
5	27 – 51
2	16 – 40
0.71	7 – 30
0.25	2 – 20
0.06	0 – 7

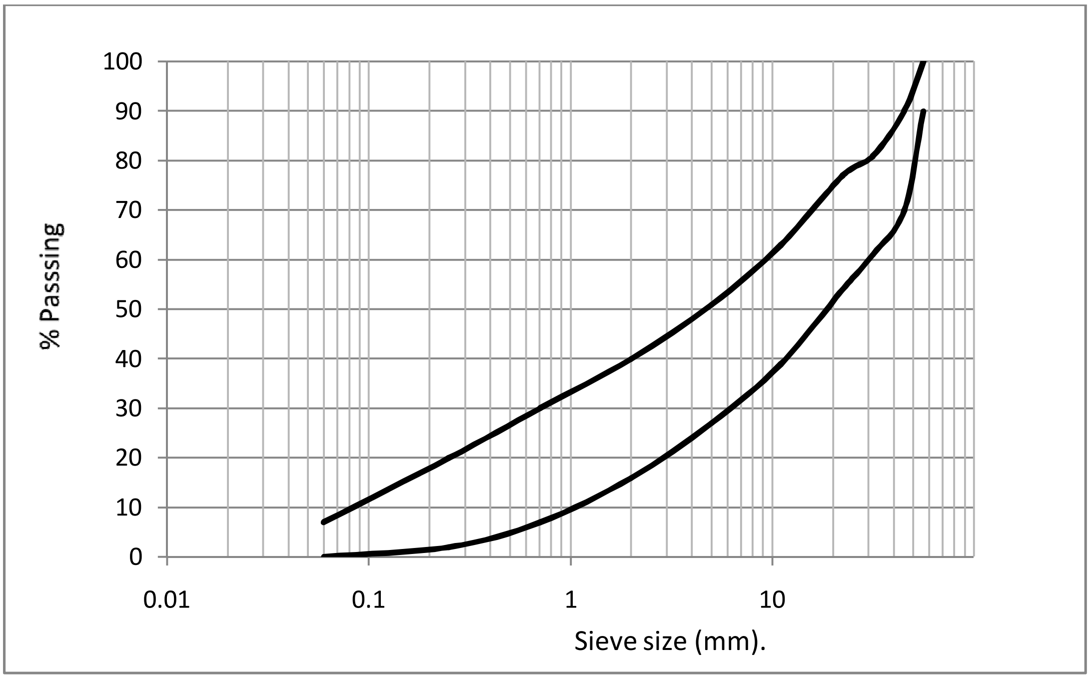

Figure 3.3 Gradation curve According to (0/56) German specification [10]

3.3 Other Characteristics

Table 3.4 presents specification according to AASHTO standards:

Table 3.4 AASHTO [10] and Palestinian standards [16] for base course material.

Specification	AASHTO Standards	Palestinian Standards
Liquid limit	Max 25%	Max 25%
Plasticity Index	Max 6%	2 - 6 %
Specific gravity (SSD) course	2.6	2.6
Specific gravity (SSD) fine	2.6	2.6
Specific gravity (OD) course	2.6	2.6
Specific gravity (OD) fine	2.6	2.6
Los Angeles Abrison	Max 45%	Max 40%
CBR (100%)	Min 80%	Min 80%
Absorption % coarse	Max 3%	Max 3%
Absorption % fine	Max 3%	3%

3.4 Conclusion

Chapter three presented AASHTO, ASTM, German and Palestinian specifications for base course materials. This research mainly uses AASHTO specification as it is the most comprehensive specification of highway field.

Chapter Four: Studied Material

4.1 Background

Three types of material were collected, conventional materials, reclaimed asphalt and demolition debris. These material are common, but here in Gaza these materials in a special case are available in large amount. Political situation, and repeated attack from Israeli forces cause huge quantities of demolition debris in addition to the damage of infrastructure facilities such as roads. These roads required urgent repair or sometimes rehabilitation, accordingly huge quantities of reclaimed asphalt are produced. In normal cases asphalt roads require repair after about ten years and may require rehabilitation or reconstruction after thirty years.

4.2 Asphalt Pavement Distresses [17]

Pavement distresses are external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination. Typical distresses are cracks, rutting, and weathering of the pavement surface. These distresses causes asphalt layer failure and hence results in quantities of reclaimed asphalt pavement. Appendix "C" is a review of the following pavement distresses:

1. Fatigue (Alligator) Cracking
2. Bleeding
3. Block Cracking and Thermal Cracking
4. Longitudinal Cracking
5. Pothole
6. Rutting

4.3 Reclaimed Asphalt Pavement in Gaza

Repeated Israeli attacks cause large damage in infrastructures, such as roads which exposed to damage several times especially arterial roads Salah El Dean, Al Rasheed and El Karama streets, which passes through border areas. These streets didn't gain required repair mainly during the siege period imposed on Gaza since 2006.

Bad conditions of these streets and other roads in Gaza strip required channel funding for roads development, repair and reconstruction. In Gaza the government decided to reconstruct several arterial streets funded by Qatar.

Tables 4.1, 4.2 and 4.3 show estimated quantities of reclaimed asphalt pavement according to Ministry of Public Work and Housing (MPWH), Directorate of roads designs [18]:

Table 4.1 Expected quantities of reclaimed asphalt pavement from reconstruction of Salah El Deen street [18].

Site	**Length m**	**Width m**	**Depth m**	**Volume m^3**	**Weight Ton**
Rafah border – Rafah eastern entrance	2,000	9	0.10	1,800	765
Rafah eastern entrance – Beny sohaila roundabout	11,000	7	0.07	5,390	2,295
Beny sohaila roundabout – Wadi Gaza	10,000	14	0.15	21,000	8,935
	6,000	14	0.09	7,560	3,215
Total					**15,210 Tons**

Table 4.2 Expected quantities of reclaimed asphalt pavement from reconstruction of El Karama street [18].

Site	Length m	Width m	Depth M	Volume m^3	Weight Ton
El Karama St.	12000	7	0.06	5040	**2145 Tons**

Table 4.3 Expected quantities of reclaimed asphalt pavement from reconstruction of El Rasheed street [18].

Site	Length m	Width m	Depth M	Volume m^3	Weight Ton
Rafah – Khalel El Wazeer mosque	30000	10.50	0.12	37800	16085
Shalehat Gaza – El Shati' camp	2000	14	0.09	2520	1070
El Shati' camp – El Forosya clup	6000	7	0.06	2520	1070
Total					**18225 Tons**

From these tables it is noted that just from these three streets about 35,580 tons of reclaimed asphalt pavement. Recycling these quantities leads to reducing lands required to making landfills in addition to reducing costs of projects that use RAP. Environmental issues of recycling also should not be neglected.

4.4 Demolition Debris in Gaza

Normally, everything has a time and cycle life, concrete structures too require repair, rehabilitation and reconstruction after its age. Removing these large volumes causes huge quantities of demolition debris. Other causes of production demolition debris are disasters as earthquakes, floods and wars. In Gaza Strip repeated Israeli attacks were the main factor of demolition debris production. This small area exposed to two wars in the last four years in addition to several attacks, every event from these results in enormous volume of demolitions. According to Ministry of public work and housing MPWH [15] about 1,125,000 tons of demolition debris results from 2009 war on Gaza, and other 50,000 tons from 2012 war. Tables 4.4 and 4.5 shows quantities of demolition debris in 2009 war according to MPWH report 2010.

Table 4.4 Total demolition buildings from 2009 war [15].

Governorate	Non-residential building	Residential building	Residential flat
North	274	756	1,409
Gaza	474	633	964
Middle	23	126	210
Khanyonis	124	270	346
Rafah	98	311	496
Total	993	2,096	3,425

Table 4.5 Demolition debris from 2009 war [15].

Sector	Weight (Ton)
Residential buildings (Total demolition)	600,000
Residential buildings (Partial demolition)	150,000
Industrial structures	60,000
Security headquarters	108,000
Mosques, schools and public buildings	50,000
Ministries buildings	72,000
Miscellaneous	85,000
Total	**1,125,000 tons**

2012 war caused demolition of 772 buildings, as 209 total residential flat demolition, major repair of 450 residential flat and other 12,000 minor repair [15].

Chapter Five: Materials and Testing Program

5.1 Samples Collection

This research deals with three types of materials, so samples were collected from these materials in appropriate quantities and representative to the actual material existing in local market, these materials are:

1. Conventional aggregates.
2. Demolition debris.
3. Reclaimed asphalt pavement.

5.1.1 Conventional Aggregates

These samples are collected from stockpiles imported from Israel, appropriate quantity was collected. After cutting the stockpiles and laying it to avoid segregation of large particles. 17 samples of average weight 35 kg for each were collected.

5.1.2 Demolition Debris

After visiting several crushers in Rafah, Al Shija'ea and Jabalia, it is noted that most of these crushers produce aggregates which are suitable for Hollow block production with small gradation Adasia (0/12.5)mm and Simsim (0/9.5) mm. But producing aggregates with large gradation Folia (0/19.5)mm, Adasia (0/12.5)mm and Simsim (0/9.5)mm was found just in "Kohail crusher" in eastern Jabalia as this crusher is specialized in production crushed aggregates for base course and has large gradation and experience in this field.

17 samples were collected with average weight of 35 kg for each.

5.1.3 Reclaimed Asphalt Pavement

More than 4 tons of reclaimed asphalt pavement were collected from Ministry of Public Work and Housing Stores - El Moghraqa. These quantities were transferred to "Kohail crusher" in eastern Jabalia to be crushed and then 17 samples of average weight 35 kg were collected.

5.2 Sample Preparation

After transfer samples to Material and Soil Labs at the Islamic university, the following steps are executed:

1. A sample of 100 kg of conventional aggregates and a sample of 100 kg of demolition debris were taken separately in pockets.
2. Three samples of about 35 kg were prepared by mixing 10% reclaimed asphalt pavement and 90% conventional aggregates, these sample are marked with R/C 10% which means 10% reclaimed asphalt pavement and 90% conventional aggregates.
3. The last step is repeated four times with rates of 20%, 30%, 40% and 50% reclaimed asphalt pavement.
4. Three samples of about 35 kg were prepared by mixing 10% of reclaimed asphalt pavement and 90% of demolition debris, these sample are marked with R/D 10% which means 10% reclaimed asphalt pavement and 90% demolition debris.
5. The last step is repeated four times with rates of 20%, 30%, 40% and 50% reclaimed asphalt pavement.

Table 5.1 shows samples label for each mix.

Table 5.1 Sets of experimental program.

		RAP content				
		10%	**20%**	**30%**	**40%**	**50%**
Conventional or Demolition	**90%**	R/C 10% R/D 10%				
	80%		R/C 20% R/D 20%			
	70%			R/C 30% R/D 30%		
	60%				R/C 40% R/D 40%	
	50%					R/C 50% R/D 50%

5.3 Tests Performed [12]

Tests were conducted on the conventional aggregates and demolition debris to have a reference for compare results of mixed reclaimed asphalt pavement with the properties of conventional aggregates and demolition debris,:

1. Sieve analysis (AASHTO-T 27)
2. Specific gravity and absorption (AASHTO-T 84 and T 85)
3. Atterberg limits (AASHTO T89 and T90)
4. Los Angeles abrasion test (AASHTO-T 96 as ASTM C131)
5. Sand equivalent (AASHTO T 176)
6. Proctor compaction test (AASHTO- T 180)
7. CBR (AASHTO- T193)
8. Bitumen extraction (AASHTO T 164)

All these tests were repeated 10 times over all mixed samples.

Other two tests were performed on reclaimed asphalt pavement which are Bitumen extraction test to indicate the rate of bitumen in the origin asphalt mixing and sieve analysis of aggregates to determine the nominal diameter of aggregates.

5.3.1 Sieve Analysis AASHTO T 27 [12]

This test method determines the particle size distribution of fine and coarse aggregates by sieving. The No. 4 sieve is designated as the division between the fine and coarse aggregate. So the sample of about 50 kg is taken and mixed throughout by turning the sample over three times by a shovel, use splitter box to split the sample to take a representative sample. Then dry sample by oven capable to maintain temperature of 105 ^{o}C until constant weight is achieved, use sieve No. 4 to divide sample between fine and coarse aggregate.

Coarse aggregate directly sieved over sieves 8" round of opining size 75, 50, 37.5, 25, 19, 12.5, 9.5 and 4.75mm. Sieves are installed from large to small opining from top to bottom and place the sample on the top sieve. Shake the sieves by hand until not more that 0.5% of the sample weight passes any sieve during one minute. Remove the top sieve, brush retained material into a pan, weight and record non-cumulative weight.

If fine aggregate that pass No. 4 is large amount take the sample weight and then take a small sample of about 1 kg weight. Washing small sample on sieve No.200 then dry sample by oven capable to maintain temperature of 105 ^{o}C until constant weight is achieved. Install sieves (8" round) of opining size 2, 1.18, 0.6, 0.425, 0.3, 0.15, and 0.075mm, these sieves are installed from large to small opining from top to bottom and place the sample on the top sieve. Shake the sieves by hand until not more that 0.5% of the sample weight passes any sieve during one minute. Remove the top sieve, brush retained material into a pan, record non-cumulative weight.

Figure 5.1 Gradation test standard sieves devices

Calculations:

After recording weights retained on each sieve the following calculation have to be done:

A : Sample weight (coarse and fine).

B : Fine sample that pass No.4.

C : Small sample weight taken from passing No.4.

D_n : Weight of retained material on sieve No.4 and above.

E_n : Weight of retained material on sieve less than No.4.

F_n : Cumulative passing less than No.4.

$$F_n = C - \text{sum}(E_n)$$

G_n : Cumulative passing No.4 and above.

$$G_n = A - \text{sum}(D_n)$$

H_n : Rate passing less than No.4 from small sample

$$H_n = F_n / C$$

I_n : Final rate Passing

$$I_n = G_n / A \quad \text{Or} \quad I_n = H_n \times B / A$$

5.3.2 Specific Gravity and Absorption for Fine Aggregate (AASHTO T84) [12]

This test determine the bulk specific gravity, bulk specific gravity in saturated surface dry aggregate and absorption of fine aggregates which are aggregates pass sieve No.4. First of all a Pycnometer filled with water is weighted and recorded, then take sample of about 1100 g of material passing sieve No.4 by using mechanical splitter. Dry the sample by oven capable to maintain temperature of 105 ^{o}C until constant weight is achieved and cool it to a comfortable handing temperature. Place the sample in a pan and cover it with water for 17 hour and then remove excess water, put the sample in a flat container and expose it to warm air with low speed and stir the sample to have uniform dry. Place metal mold in the form of a frustum of a cone that large diameter down and fill it with dried sample and tamp the surface of the material in the mold 25 times with the tamper. Each drop of the tamper should start 5 cm above the top of the fine aggregate. Remove the cone and notice the shape of the sample, If surface moisture is still present in the sample, the fine aggregate will retain the molded shape and additional drying is required, but if 25 to 75% of the top diameter of the cone slumps that means the sample is in saturated surface dry state.

After having saturated surface dry sample weight around 500g and put it in the pycnometer. Fill the pycnometer partially with water, remove bubbles using suction machine and agitate the pycnometer several times during bubble removal. After remove bubbles fill the pycnometer with water and weight it and record, weight an empty pan and pour the sample in the pan and dry it by oven capable to maintain temperature of 105 ^{o}C until constant weight is achieved then weight the dry sample.

Figure 5.2 Pycnometer device for determining specific gravity

Calculations:

The following equations give the required items:

A: Weight of dry sample.

B: Weight of pycnometer filled with water.

C: Weight of pycnometer filled with sample and water.

S: Weight of saturated surface dry sample.

Bulk Specific Gravity = A/(B + S - C)

Bulk Specific Gravity (Saturated Surface Dry) = S/(B + S - C)

Apparent Specific Gravity = A/(B+A-C)

Absorption = [(S-A)/A] x 100

5.3.3 Specific Gravity and Absorption for Coarse Aggregate (AASHTO T 85) [12]

This test determine the bulk specific gravity, bulk specific gravity in saturated surface dry aggregate and absorption of coarse aggregates which are aggregates returned on sieve No.4. Wash the sample of weight about 8 Kg on sieve No.4 and soak it for 17 hours in water, Remove the sample from the water and roll in a large absorbent cloth until all visible films of water are removed. At this point the sample is in a saturated surface dry condition (SSD). Weight the sample and record it. Then place the saturated surface dry sample in a basket which is immersed in water and shake the basket and record the weight of sample immersed in water, remove the sample from the basket and dry it by oven capable to maintain temperature of 105 ^{o}C until constant weight is achieved.

Calculations:

A : Weight of dry sample in air.

B : Weight of saturated surface dry sample in air.

C : Weight of saturated sample in water.

Bulk Specific Gravity = A/(B - C)

Bulk Specific Gravity SSD = B/(B - C)

Apparent Specific Gravity = A/(A - C)

Absorption = [(B - A)/A] x 100

5.3.4 Liquid Limit (AASHTO T 89) [12]

The Liquid Limit of a soil is an index corresponding to the moisture content at which the soil passes from a plastic to a liquid state. Liquid limit is used in conjunction with the Plastic Limit (AASHTO T-90) to determine the Plasticity Index (PI) of a soil. Liquid Limit and PI provide an indication of the "clayeyness" of a soil. Material with a high Liquid Limit and PI will be unsuitable for many construction applications due to this "clayeyness." Conversely, material with a relatively low Liquid Limit and PI is generally desirable in highway construction.

Prepare a sample of 100 g passing 425 μm (No.40) sieve and add appropriate water and mix the sample. Put the sample in the mold on three layers each layer hit the mold on the table to remove bubbles from the sample. Adjust the surface of the sample and use the Penetrometer device. Put the mold under the cone and let the cone touch the surface of the sample then allow the cone to drop freely for five seconds, the depth of cone penetration in the sample is recorded and a take a sample to indicate the water content.

Repeat the test several times to have measures above and lower than 20mm penetration and draw the results and indicate the water content related to penetration of 20mm.

Figure 5.3 Penetrometer device for determining liquid limit

5.3.5 Plastic Limit (AASHTO T 90) [12]

The plastic limit of a soil is the lowest water content at which the soil remains plastic. After liquid limit test take the remain sample plastic enough to be shaped into a ball without sticking to the fingers. Set aside and allow to air dry until completion of the liquid limit test. If the sample is too dry, add more water and re-mix, roll between fingers and the ground glass plate or piece of paper with sufficient pressure to roll the sample into a uniform thread about 1/8" in diameter throughout its length. Roll at a rate of 80 to 90 strokes per minute. A stroke is a complete forward and back motion, returning to the starting place. The rolling procedure should be completed in two minutes.

When the diameter of the thread reaches 1/8", break the thread into six or eight pieces and squeeze the pieces together between the thumbs and fingers of both hands into a roughly uniform ellipsoidal shape and re-roll. Continue this procedure until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the thread has a diameter greater than 1/8". This is considered a satisfactory end point provided that the soil has been previously rolled into a thread 1/8" in diameter. Gather the portion of the crumbled soil together and place in a container and cover. Repeat this procedure until the entire 8-g specimen is completely tested. Weigh to the nearest 0.01 g and record. Determine the moisture content.

Plastic Index

The plasticity index of a soil is the numerical difference between the liquid limit (L.L) and the plastic limit (P.L).

P.I = L.L – P.L

5.3.6 Los Angeles Abrasion and Impact (AASHTO T 96 as ASTM C131) [14]

The Los Angeles (L.A.) abrasion test is a common test method used to indicate aggregate toughness and abrasion characteristics. The standard L.A. abrasion test subjects a coarse aggregate sample (retained on the No. 12 (1.70 mm) sieve) to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres. After being subjected to the rotating drum, the weight of aggregate that is retained on a No. 12 (1.70 mm) sieve is subtracted from the original weight to obtain a percentage of the total aggregate weight that has broken down and passed through the No. 12 (1.70 mm) sieve. Therefore, an L.A. abrasion loss value of 40 indicates that 40% of the original sample passed through the No. 12 (1.70 mm) sieve.

Twelve steel ball of 46.8mm diameter and mass between 390 and 445g are used as grade "A" is chosen therefore sample of 5000g is prepared that 1250g of aggregate returned on each sieve 25, 19, 12.5 and 9.5mm.

Figure 5.4 Los Angeles device

5.3.7 Sand Equivalent (AASHTO T 176) [12]

Plastic fines in graded aggregates by use of the sand equivalent test a rapid field test to show the relative proportions of fine dust or claylike material in graded aggregates. The test procedures is as follow:

- Prepare the calcium chloride solution by diluting one measuring tin (85 ± 5 mL) of stock calcium chloride to 3.8 liter of distilled or demineralized water. The working solution has a maximum shelf life of 30 days.
- Prepare a sample of about 1 to 1.5 kg of aggregate that passes from sieve No.4, then take two samples by using small splitter,
- Put each sample in measuring tin then put it in the graduated cylinder then add 10.16mm of the solution to the sample and Allow the wetted specimen to stand undisturbed for 10 ± 1 minutes.
- Stopper the cylinder and shake gently to loosen the material. This can be achieved by partially inverting the cylinder and shaking it simultaneously. After loosening the material, place the cylinder in a mechanical shaker for 45±1 seconds.

- Following the shaking, set the cylinder upright and remove the stopper. Using the irrigation tube, rinse material on the cylinder wall down with the calcium chloride solution as the irrigation tube is being lowered in the cylinder. Force the irrigation tube through the material to the bottom of the cylinder using a gentle stabbing and twisting motion. Continue to gently stab and twist the irrigation tube until the calcium chloride solution approaches the 381 mm mark. Then raise the irrigation tube slowly at a rate that maintains the liquid level at about the 381 mm mark as the irrigation tube is being removed. Stop the flow of the calcium chloride solution just before the irrigation tube is entirely withdrawn. Adjust the calcium chloride solution level to 381mm.
- Allow the cylinder to sit undisturbed for 20 minutes ± 15 seconds.
- Read and record the clay column height, next determine the sand reading. This is done by gently lowering the weighted foot into the cylinder until it comes to rest.
- Calculate the sand equivalent by dividin`g the sand reading by the clay reading and multiply the results by 100. The equation is as follows:

  Sand Equivalent = (Sand reading/Clay reading) x 100

Figure 5.5 Mechanical shaker device for sand equivalent test

Figure 5.6 Sand Equivalent devices

5.3.8 Proctor Compaction Test (AASHTO T 180) [12]

This test method determines the relationship between the moisture content and the density of soils compacted in a mold. Method "C" was used as more than 20% of the sample retained on sieve 9.5mm. Take a sample of 29 kg from the aggregates, just aggregates that pass sieve 19mm is used and aggregates retain on sieve 19 have to be replaced by aggregates pass sieve 19mm and retain on sieve No.4.

Prepare four or five samples with different water content that the optimum water content is among these samples (By experience), and take a small sample of about 5.9 kg from each sample to apply the test. Weight the mold of 6" diameter and record. Fill the mold with five layers, compact each layer with 56 blows with rammer of weight about 4.54 kg from distance 457.2mm.

Level the surface and if there is some potholes fill it by material pass sieve

No.4, then clean the mold from outside and weight the mold and the sample, take a small sample in a pan to determine water content of the sample. Repeat the test for each sample with different water content and record.

Calculations:

Calculate the wet density by using the following formula:

Wet Weight of Soil = Weight of Mold + Soil – Weight of Mold

Wet Density = Wet Weight of Soil/Volume of Mold

Calculate the percent moisture to the nearest 0.1% using the following formula:

% Moisture = [(Wet Weight – Dry Weight)/(Dry Weight – Can)] x100

Compute and record dry density by th formula as follows:

Dry Density = (Wet Density X 100)/(100 + % Moisture)

After all the results are plotted, draw a smooth flowing curve through or close to the plotted points. From the peak of the curve, select the maximum dry density and optimum moisture.

Figure 5.7 Proctor compaction test devices

5.3.9 California Bearing Ratio CBR (AASHTO T 180) [12]

CBR is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. The following steps show the test procedures:

- Prepare the sample as aggregates that pass sieve 19mm is used and aggregates retain on sieve 19 have to be replaced by aggregates pass sieve 19mm and retain on sieve No.4. Determine water content of the sample and add water to have water content that is optimum (From proctor test).
- Prepare the mold of 15.24cm and height 17.78mm with extension 5.08cm. weight the mold and put a spacer disc of 4.77 cm height, then Fill the mold with five layers, compact each layer with 56 blows with rammer of weight about 4.54 kg from distance 457.2mm. Level the surface.
- Remove the spacer disc and indicate the weight of mold and compacted soil and put a surcharge of 4.54 kg and soak the mold for four days, then remove the mold from water for 15 minutes.
- Place the mould assembly with the surcharge weights on the penetration test machine. Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
- Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, and 7.5 mm
- After all the results are plotted, draw a smooth flowing curve through the plotted points, If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin.

Calculation

C.B.R. = PT/PS x 100

where PT = Corrected test load corresponding to the chosen penetration from the load penetration curve.

PS = Standard load for the same penetration taken from the following table

Table 5.2 Standard CBR sample penetration / load.

Penetration (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater that at 5 mm and in such a case it shall be taken as C.B.R. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken.

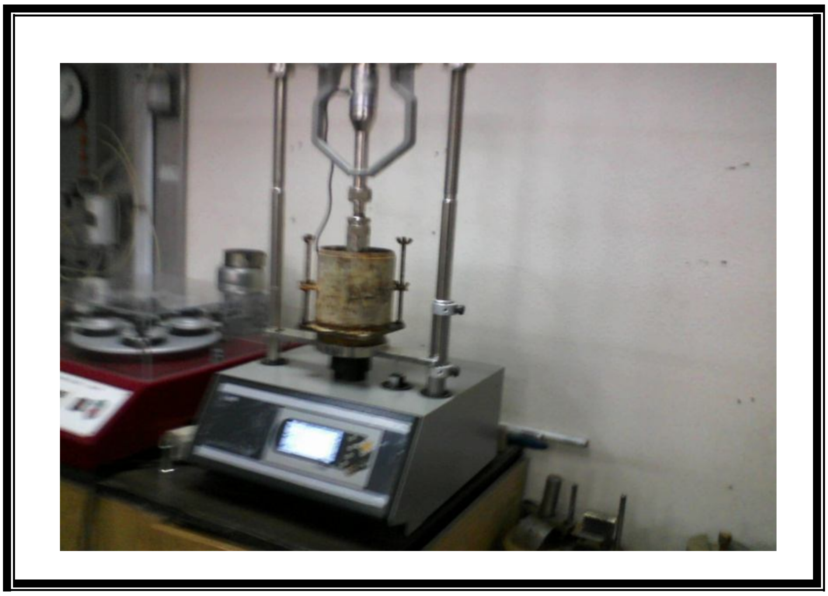

Figure 5.8 CBR device

Figure 5.9 CBR molds

5.3.10 Bitumen Extraction (AASHTO T 164) [12]

This method covers procedures for the quantitative determination of bitumen in hot-mixed paving mixtures, mixtures containing liquid bituminous materials, and pavement samples.

A sample of weigh an approximate 500 to 2500 gram is taken, The mixture is placed in a large flat pan and warmed until it can be handled at temperature 163 ± 5^{o}C. Separate the particles of the mixture as uniformly as possible using care not to fracture the mineral particles. Add a solvent and cover the sample in the bowl, and allow sufficient time for the solvent to disintegrate the sample (not over 1 hour). Place the bowl containing the sample and the solvent in the extraction apparatus. Dry and weigh the filter ring and place it around the edge of the bowl. Clamp the cover on the bowl tightly and place a 2000 mL Florence flask under the drain to collect the extract. Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain. Allow the machine to stop, add 200 mL of solvent and repeat the procedure. Use sufficient 200 mL solvent additions (not less than three) so that the extract is clear and not darker than a light straw color. Collect the extract and the washings in a 2000 mL Florence flask.

Weight aggregates to indicate the percent of bitumen which is the different between original sample weight and the aggregate weight.

Figure 5.10 Centrifugal Extraction machine

Chapter Six: Results and Discussion

6.1 Introduction

Comprehensive testing program was designed to determine the applicability of using reclaimed asphalt pavement and demolition debris as aggregates in base layer. Several tests were conducted to investigate properties of mixes of conventional debris and reclaimed asphalt and these tests were repeated for mixes of demolition debris and RAP. Results are shown in Appendix "A".

6.2 Material Characterization

6.2.1 Conventional Material and Demolition Debris

This section discuss the results of material properties as sieve analysis, bulk specific gravity (SSD) and absorption tests, liquid limit and plastic limit of the base material which are conventional base course and demolition debris. In addition to classify these material by AASHTO classification.

The result of dry sieve analysis is shown in Table 6.1, results is compared with AASHTO specification (See Appendix B) for fine base course in Figure 6.1, the nominal maximum size of conventional base course is 37.5mm and the nominal maximum size of demolition debris is 37.5mm too.

Table 6.1 Gradation of conventional material and demolition debris

Sieve size #	Sieve size mm	Conventional material	Demolition debris
2"	50	100.00	100.00
1.5"	37.50	90.86	93.69
1"	25	78.87	75.48
3/4"	19	69.68	61.61
1/2"	12.5	57.50	41.63
3/8"	9.5	50.28	35.43
#4	4.75	37.62	25.17
#10	2.00	26.41	20.29
#16	1.180	21.23	18.71
#30	0.600	16.91	16.44
#40	0.425	15.19	13.83
#50	0.300	13.97	10.31
#100	0.150	11.70	4.04
#200	0.075	9.95	2.87

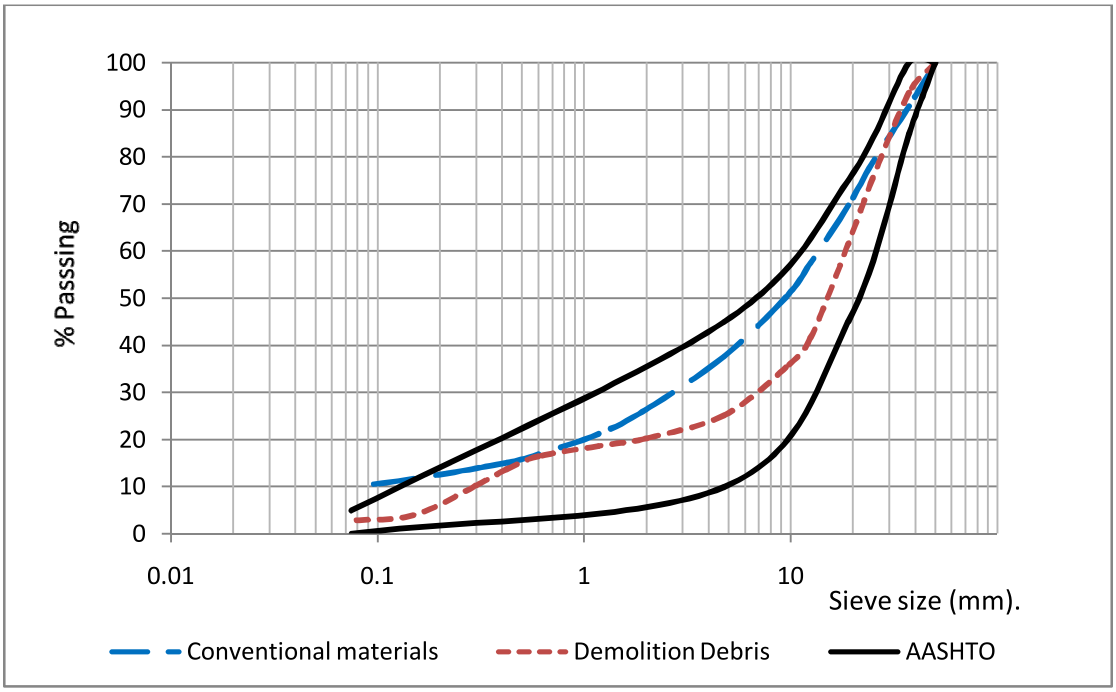

Figure 6.1 Gradation curve of conventional materials and demolition debris compared with AASHTO limits

Table 6.2 Bulk specific gravity and absorption of conventional materials and demolition debris

Test type	Conventional materials	Demolition debris
Bulk specific gravity SSD (Fine)	2.60	2.48
Bulk specific gravity SSD(Coarse)	2.44	2.36
Absorption (Fine)	5.94 %	4.8 %
Absorption (Coarse)	5.64 %	5.63 %

Table 6.3 Atterberg limits for convention materials and demolition debris

Test type	Conventional materials	Demolition debris
Liquid limit	20.55 %	22.35 %
Plastic limit	17 %	NP
Plastic Index	3.55 %	-

NP: Non - plastic

According to AASHTO classification system (See Appendix B):

- conventional materials is gravel materials as less than 35% passes sieve #200.

As $d_{10} = 0.09$, $d_{30} = 2.7$, $d_{60} = 13$

$C_u = d_{60} / d_{10}$

$= 144 > 6$

$C_c = (d_{30})^2 / (d_{60} \times d_{10})$

$= 6.2 > 3$

So conventional material is Gap graded.

Soil classification is A-1-a.

- Demolition debris is gravel materials as less than 35% passes sieve #200.

As $d_{10} = 0.3$, $d_{30} = 6$, $d_{60} = 19$

$C_u = d_{60} / d_{10}$

$= 63.3 > 6$

$C_c = (d_{30})^2 / (d_{60} \times d_{10})$

$= 6.3 > 3$

So Demolition debris material is Gap graded

Soil classification is A-1-a.

6.2.2 Reclaimed Asphalt Pavement Tests

6.2.2.1 Bitumen Extraction Test (AASHTO T 164)

A sample of reclaimed asphalt pavement was taken, Bitumen extraction test showed that the bitumen ratio in the mixture was 5.75%

6.2.2.2 Gradation of Aggregate Used in RAP

Table 6.4 shows gradation of aggregates that are used in the mixture of reclaimed asphalt pavement, which illustrated that the fresh asphalt is 0.5 inch mixture.

Table 6.4 Gradation of aggregates used in reclaimed asphalt pavement

Sieve size (#)	Sieve size (mm)	RAPs aggregate
3/4"	19	100.00
1/2"	12.5	87.75
3/8"	9.5	77.46
#4	4.75	57.23
#10	2.00	39.91
#16	1.180	30.17
#30	0.600	22.59
#40	0.425	18.80
#50	0.300	14.47
#100	0.150	7.44
#200	0.075	4.73

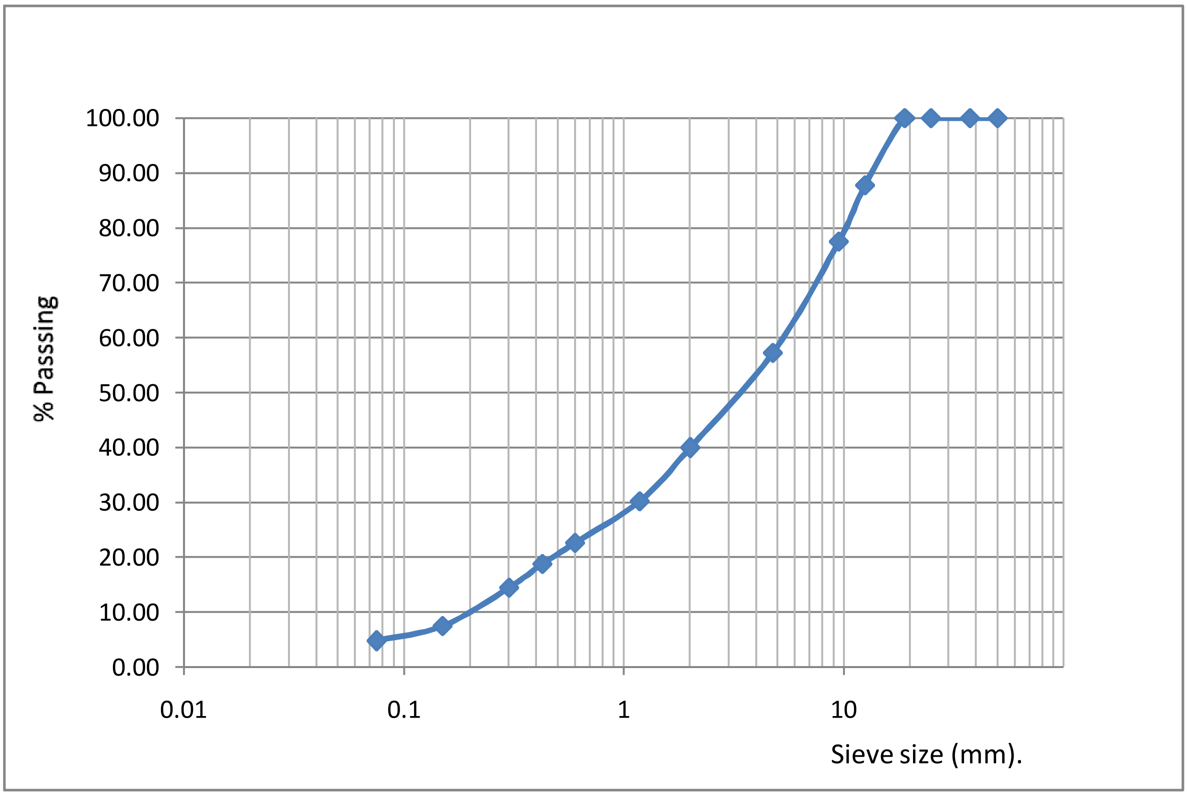

Figure 6.2 Gradation curve of aggregates used in reclaimed asphalt pavement

- Aggregates used in reclaimed asphalt pavement is gravel material as less than 35% passes sieve #200.

  As $d_{10} = 0.2$, $d_{30} = 1.2$, $d_{60} = 5$

  $C_u = d_{60} / d_{10}$

  $= 25.0 > 6$

  $C_c = (d_{30})^2 / (d_{60} \times d_{10})$

  $= 1.44 < 3$

So Aggregate used in reclaimed asphalt pavement is Well graded

Soil classification is A-1-a (See App. A AASHTO soil classification).

6.3 Tests Result

This section presents test results for both base materials conventional materials and demolition debris mixed with reclaimed asphalt pavement, these tests are Sieve analysis, Compaction modified proctor, Atterberg limits, Specific gravity, Absorption, California bearing ration CBR, Sand equivalent and Los Angeles abrasion.

6.3.1 Conventional Materials and Reclaimed Asphalt Pavement

6.3.1.1 Gradation

Table 6.5 and Figure 6.3 show that the gradation curve of conventional material is near to upper limits of AASHTO specifications and with increasing reclaimed asphalt ratio the mixture becomes more coarse and the curve is going toward lower limits of AASHTO specifications, as reclaimed asphalt pavement more coarse than conventional materials.

Table 6.5 Gradation of conventional material with different reclaimed asphalt pavement content

Sieve size #	Sieve size mm	Conventional material	R/C 10%	R/C 20%	R/C 30%	R/C 40%	R/C 50%
2"	50	100	100.00	97.52	98.68	93.34	93.31
1.5"	37.50	90.86	89.90	87.97	88.24	81.02	79.76
1"	25	78.87	72.88	74.73	72.75	65.85	62.34
3/4"	19	69.68	64.92	66.31	64.15	57.74	52.93
1/2"	12.5	57.5	51.49	51.64	49.96	44.88	37.47
3/8"	9.5	50.28	45.01	44.10	43.61	37.31	30.75
#4	4.75	37.62	33.31	31.83	31.36	26.06	20.75
#10	2.00	26.41	23.74	21.72	22.39	18.71	14.56
#16	1.180	21.23	18.91	17.09	18.02	15.22	11.59
#30	0.600	16.91	14.78	13.32	14.55	12.24	9.33
#40	0.425	15.19	13.13	11.94	12.98	10.78	8.27
#50	0.300	13.97	10.41	10.55	11.60	9.14	7.29
#100	0.150	11.7	8.83	8.55	9.28	6.63	5.68
#200	0.075	9.95	8.44	7.72	7.92	5.62	4.87

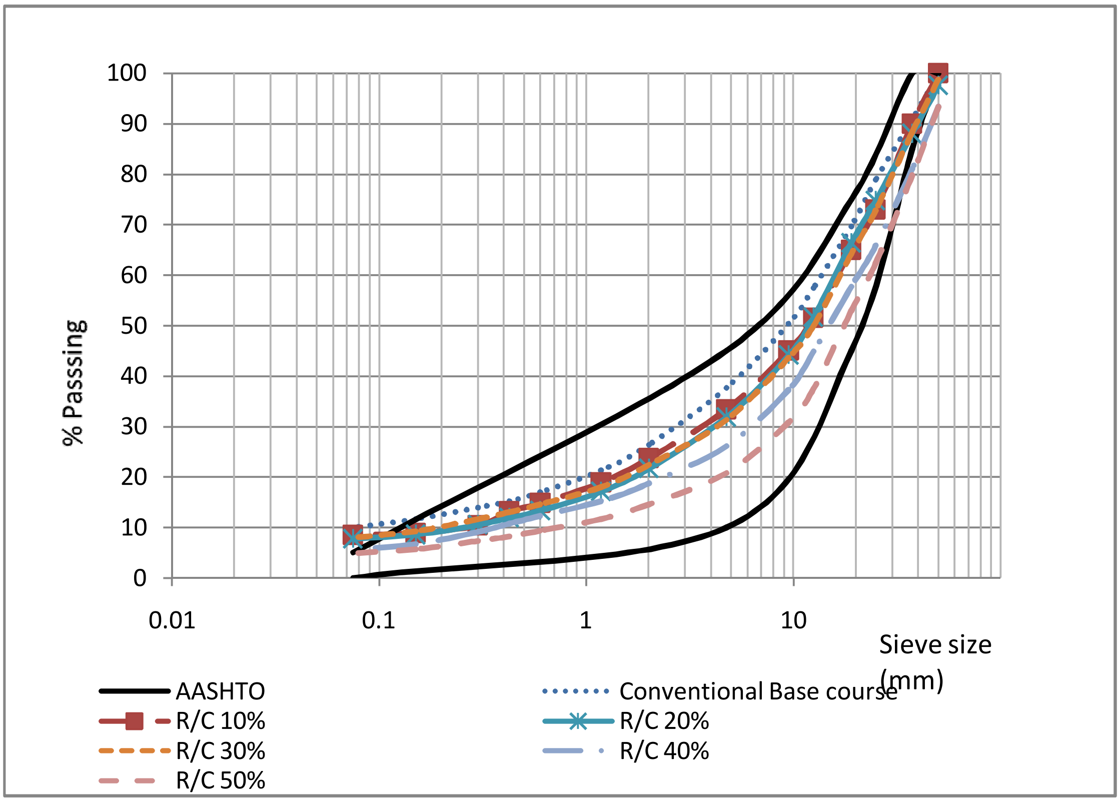

Figure 6.3 Gradation curve of Conventional material with different reclaimed asphalt pavement content

6.3.1.2 Compaction

Using modified Proctor test the results in table 6.6 are obtained for the mix of conventional material with reclaimed asphalt pavement for different ratios. The results showed that maximum dry density decreased when reclaimed asphalt pavement ratio increased, as density of reclaimed asphalt pavement is less than the density of conventional aggregates. That agreed with previous studies reviewed by McGarrah [1]. While optimum moisture content increased with increasing reclaimed asphalt pavement content up to 30% and then decreased with increasing the reclaimed asphalt pavement content as RAP absorption is less than conventional aggregates .

Table 6.6 Modified Proctor compaction for conventional material with different reclaimed asphalt pavement content

Material	Max. Dry Density (MDD) ton/m^3	Optimum Water content (OWC)%
R/C 10%	2.14	7.9
R/C 20%	2.11	8.4
R/C 30%	2.12	8.8
R/C 40%	2.11	8.4
R/C 50%	2.10	8.2

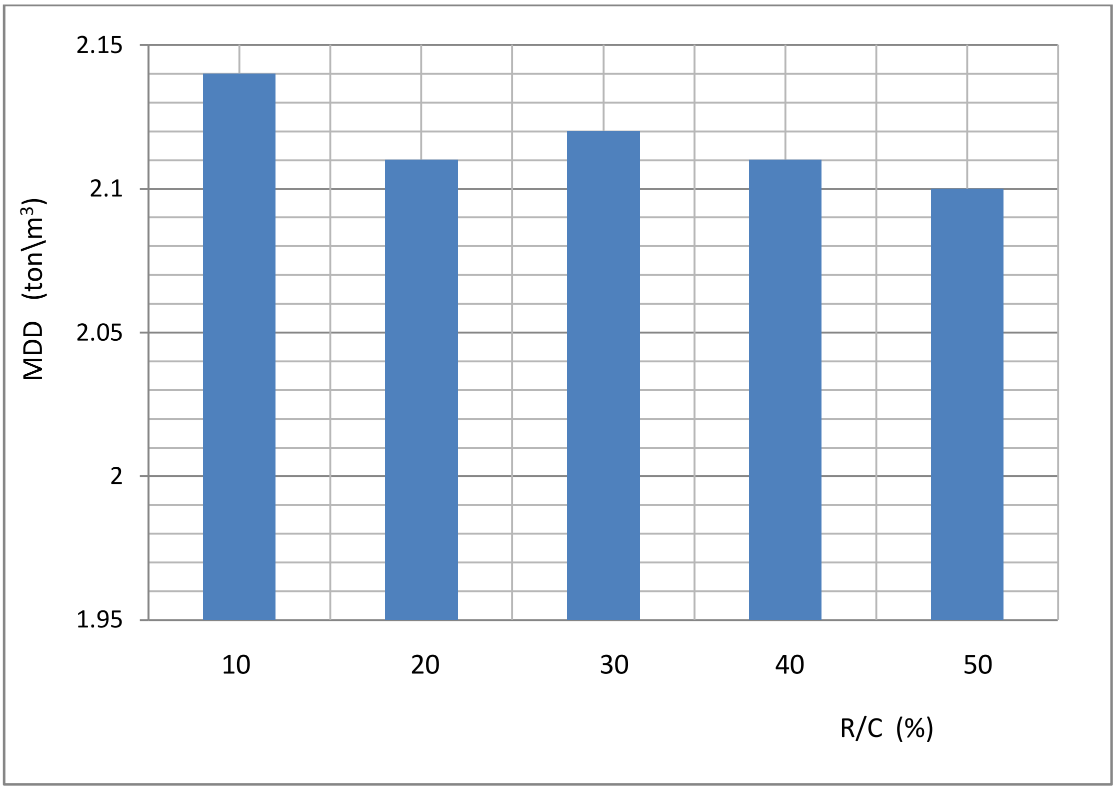

Figure 6.4 Maximum dry density for different R/C

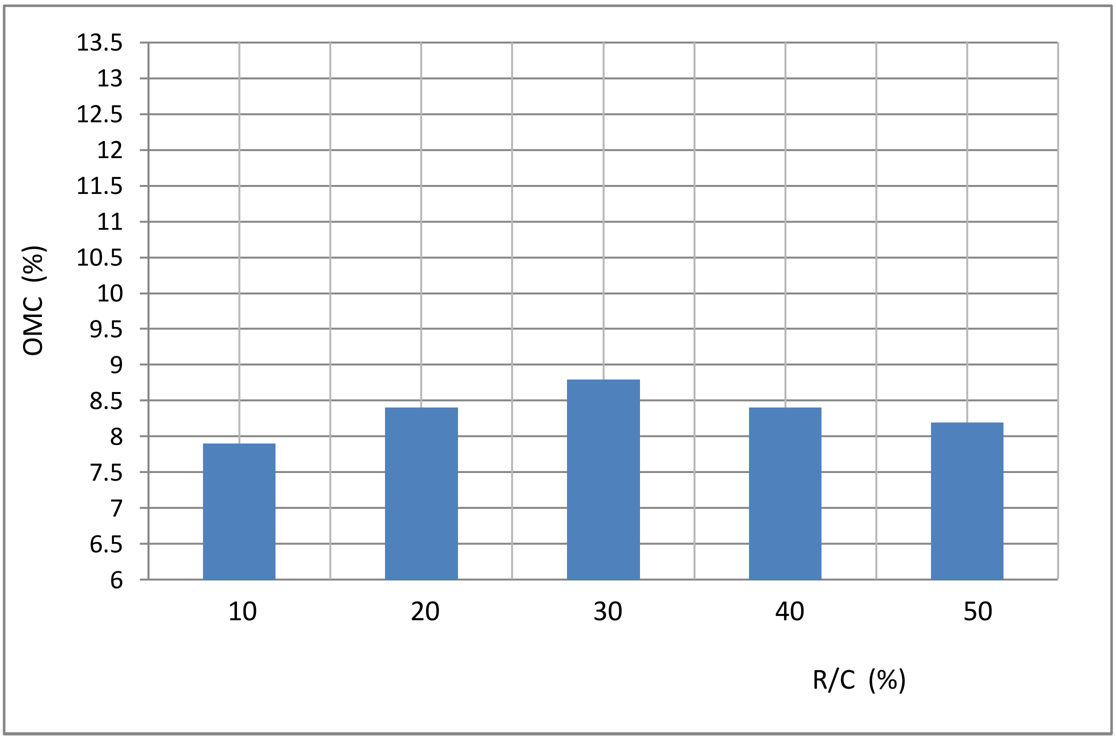

Figure 6.5 Optimum water content for different R/C

6.3.1.3 Atterberg Limits

Table 6.7 shows results of liquid limit and plastic index. Plastic Index is greater than specifications (PI<6) for conventional material with 20% RAP. Plasticity index has best value (2.2%) for conventional material with 40% RAP and satisfy specification.

Table 6.7 Atterberg limits for conventional material with different reclaimed asphalt pavement content

Material	L.L (AASHTO requirement Max 25%)	P.L	P.I (AASHTO requirement Max 6%)
Conventional material	20.55	17	3.55
R/C 10%	21.6	16.5	5.1
R/C 20%	21.8	13.1	8.7
R/C 30%	20.6	16.5	4.1
R/C 40%	19.6	17.4	2.2
R/C 50%	20.1	16	4.1

6.3.1.4 Specific Gravity and Absorption

Table 6.8 shows the bulk specific gravity (B.S.G) in saturated surface dry condition (SSD) didn't affect by adding reclaimed asphalt pavement, but absorption of fine and coarse aggregate decreases with increasing the reclaimed asphalt pavement ratio as aggregates in RAP covered with bitumen which decreases absorption.

Table 6.8 Bulk specific gravity SSD and Absorption for conventional material with different RAP content.

Material	Fine Aggregate		Coarse Aggregate	
	Bulk S.G SSD	Absorption	Bulk S.G SSD	Absorption
Conventional base course	2.60	5.94	2.44	5.64
R/C 10%	2.56	4.76	2.46	4.03
R/C 20%	2.60	3.94	2.41	3.81
R/C 30%	2.63	2.25	2.43	4.74
R/C 40%	2.58	3.59	2.41	3.75
R/C 50%	2.63	2.65	2.45	4.09

6.3.1.5 California Bearing Ratio Test (CBR)

Tests results showed that California bearing ratio (CBR) decreased with increasing the reclaimed asphalt pavement despite that minimum CBR is 93% which is greater than what is required in standards (80%). Cooley [3] indicated too that CBR values decreases when RAP content increased. Table 6.9 and Figure 6.6 show the results:

Table 6.9 CBR for conventional material with different RAP content.

Material	CBR
Conventional material	117 %
R/C 10%	115 %
R/C 20%	121 %
R/C 30%	104 %
R/C 40%	104 %
R/C 50%	93 %

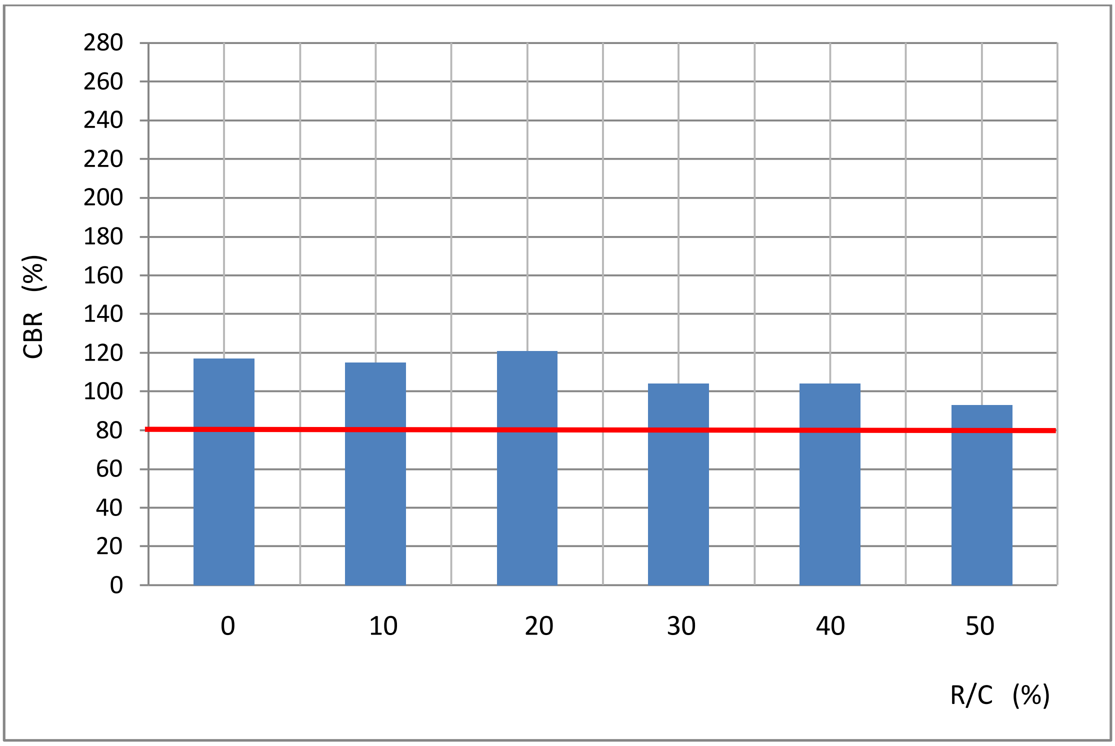

Figure 6.6 CBR for different R/C ratios

6.3.1.6 Sand Equivalent

Tests results showed that the sand equivalent is low for conventional material comparing to specification, where it is required greater than 40%. Increasing reclaimed asphalt pavement improved sand equivalent from 22.7% to 26.41% as RAP don't contain filler (clay particles). Although it does not satisfy standard requirement. Table 6.10 and Figure 6.7 illustrate the test results.

Table 6.10 Sand equivalent for conventional material with different reclaimed asphalt pavement content.

Material	Sand Equivalent
Conventional material	22.7 %
R/C 10%	23.15 %
R/C 20%	23.08 %
R/C 30%	22.44 %
R/C 40%	25.46 %
R/C 50%	26.41 %

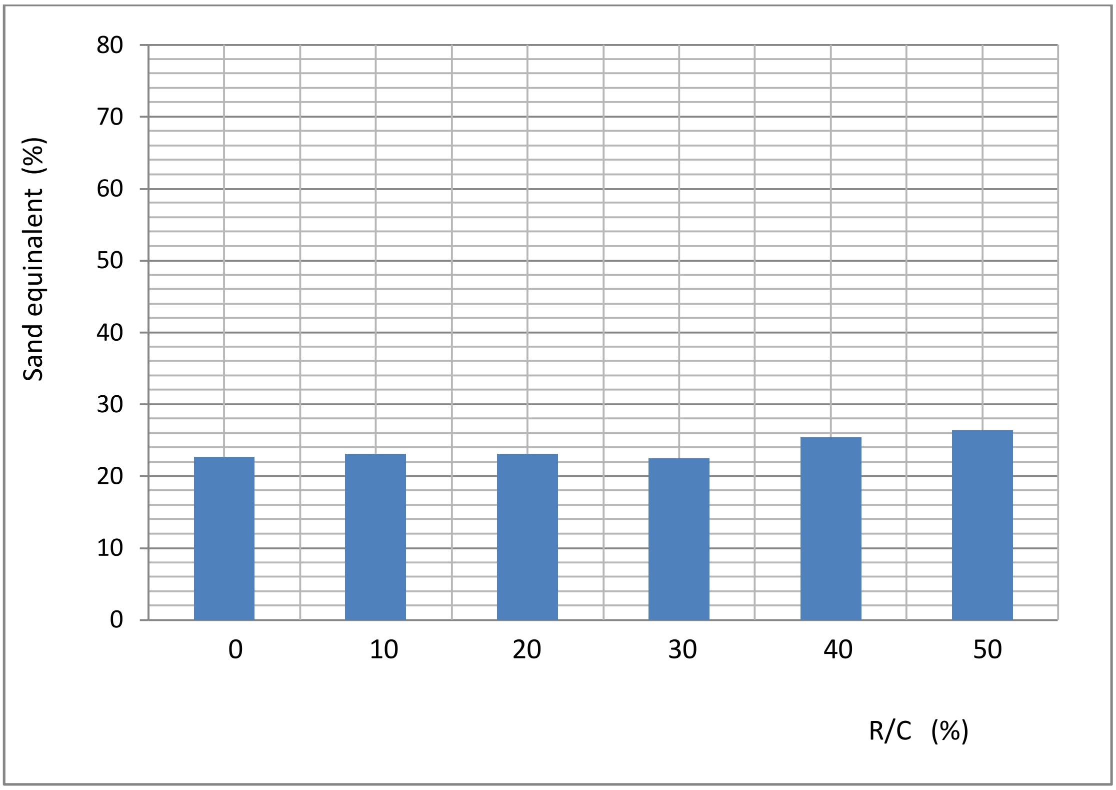

Figure 6.7 Sand equivalent for different R/C

6.3.1.7 Los Angeles Test

Tests results showed that generally there is no significant change on Los Angeles ratio after mixing RAP with conventional material. Table 6.11 and Figure 6.8 illustrate Los Angeles test results.

Table 6.11 Los Angeles for conventional material with different reclaimed asphalt pavement content

Material	Los Angeles
Conventional material	32.4 %
R/C 10%	32.7 %
R/C 20%	31.8 %
R/C 30%	32.2 %
R/C 40%	32.3 %
R/C 50%	29.3 %

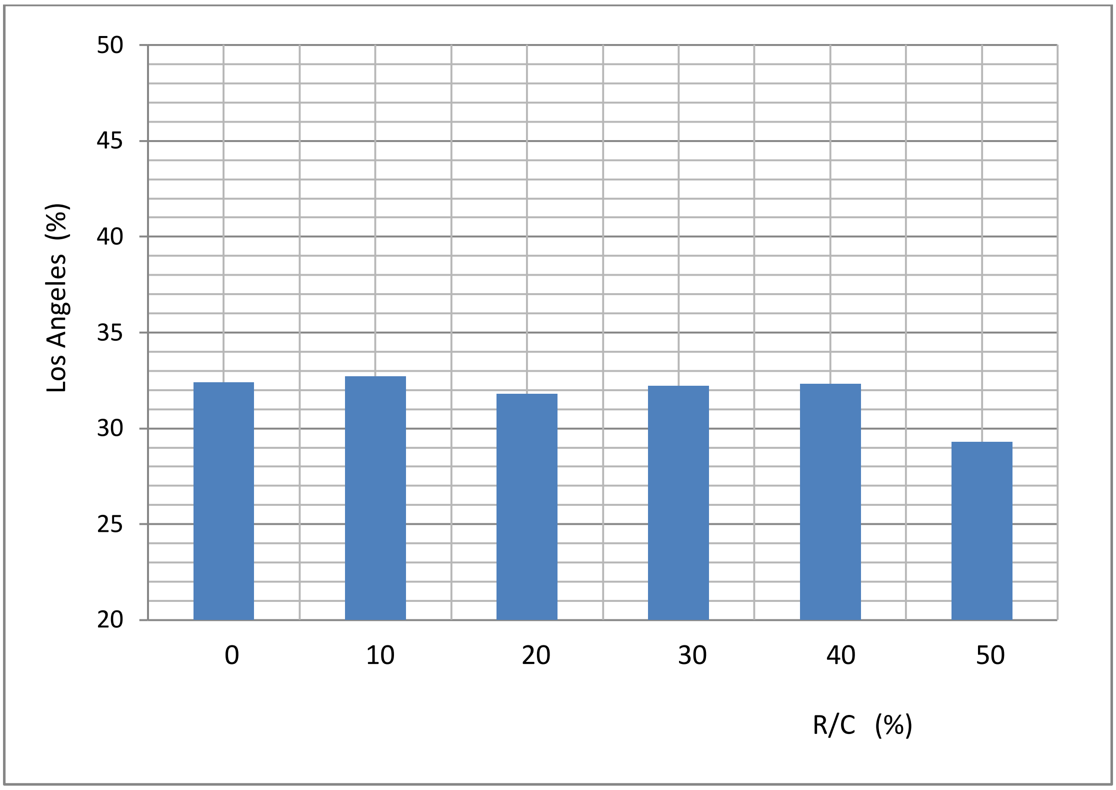

Figure 6.8 Los Angeles ratio for different R/C

6.3.1.8 Results Summary

Table 6.12 summarize results of adding reclaimed asphalt pavement to conventional material.

Table 6.12 Results summary for conventional materials with different reclaimed asphalt pavement content

Test	AASHTO Requirement	C.B	R/C 10%	R/C 20%	R/C 30%	R/C 40%	R/C 50%
Absorption fine	Max 3%	5.94	4.76	3.94	2.25	3.39	2.65
Absorption course	Max 3%	5.64	4.03	3.81	4.74	3.75	4.09
Bulk S.G SSD fine	2.6	2.60	2.56	2.60	2.63	2.58	2.63
Bulk S.G SSD course	2.6	2.44	2.46	2.41	2.43	2.41	2.45
L.L	Max 25%	20.55	21.60	21.80	20.60	19.60	20.10
P.L		17.00	16.50	13.10	16.50	17.40	16.00
P.I	Max 6%	3.55	5.10	8.70	4.10	2.20	4.10
Max dry density		2.13	2.14	2.11	2.12	2.11	2.10
Optimum water		11.00	7.90	8.40	8.80	8.40	8.20
CBR	Min 80%	117	115	134	99	104	93
Los Angeles	Max 45%	32.40	32.70	31.80	32.20	32.30	29.30
Sand equivalent	Min 40%	22.70	23.15	23.08	22.44	25.46	26.41

6.3.2 Demolition Debris and Reclaimed Asphalt Pavement

6.3.2.1 Gradation

Table 6.13 and figure 6.9 show that the gradation curve of demolition debris is in middle between limits of AASHTO specifications and with increasing reclaimed asphalt ratio the curve is going toward lower limits of AASHTO specifications, and it is clear that 50% of reclaimed Asphalt pavement curves is so closed to the lower limit.

Table 6.13 Gradation for demolition debris with different reclaimed asphalt pavement content

Sieve size #	Sieve size mm	Demolition debris	R/C 10%	R/C 20%	R/C 30%	R/C 40%	R/C 50%
2"	**50**	100.00	95.65	96.11	100.00	98.17	97.89
1.5"	**37.50**	93.69	90.52	89.94	87.91	88.49	81.57
1"	**25**	75.48	69.16	70.41	71.31	70.84	60.62
3/4"	**19**	61.61	58.53	57.20	59.10	60.89	51.43
1/2"	**12.5**	41.63	34.86	33.78	35.78	35.88	32.04
3/8"	**9.5**	35.43	26.48	24.93	27.41	27.27	24.81
#4	**4.75**	25.17	16.22	14.54	15.75	14.63	15.77
#10	**2.00**	20.29	13.10	11.13	11.90	10.38	12.20
#16	**1.180**	18.71	11.93	9.97	10.62	9.14	10.80
#30	**0.600**	16.44	10.22	8.51	9.16	7.91	9.19
#40	**0.425**	13.83	8.40	7.07	7.69	6.78	7.79
#50	**0.300**	10.31	6.43	5.41	5.74	5.06	5.73
#100	**0.150**	4.04	3.13	2.77	2.56	2.53	2.46
#200	**0.075**	2.87	2.50	2.23	2.08	2.04	1.96

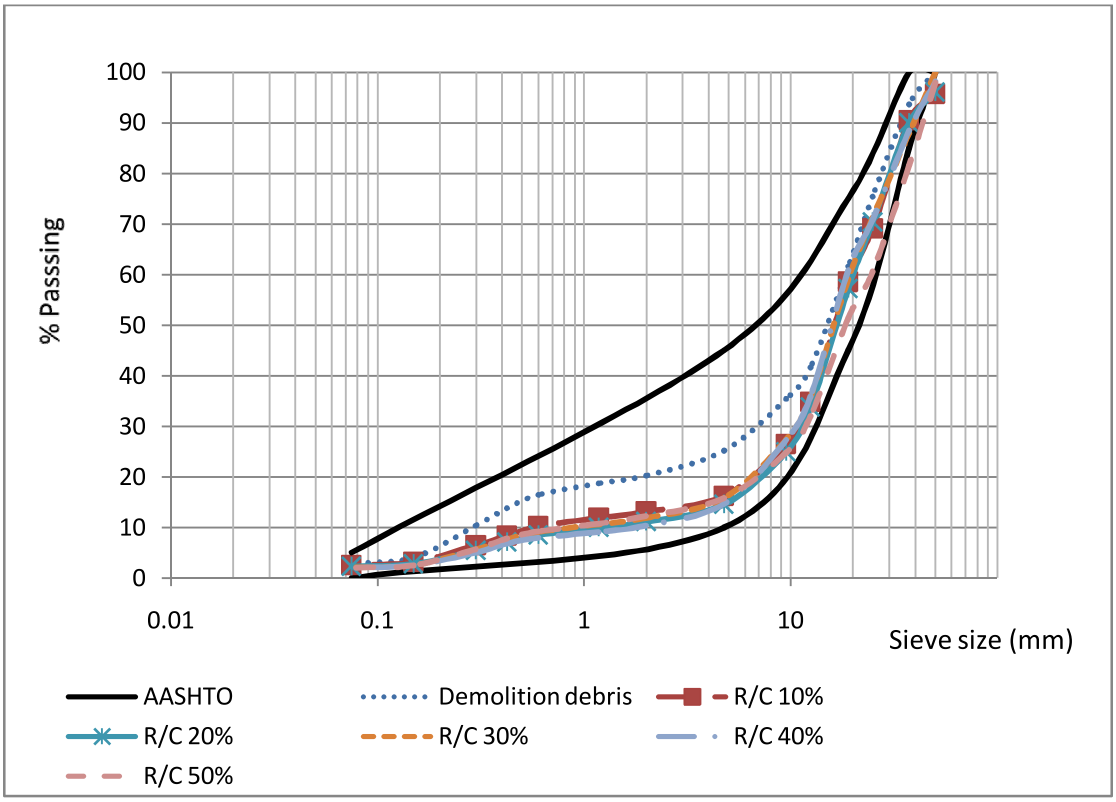

Figure 6.9 Gradation curve of demolition debris with different reclaimed asphalt pavement content

6.3.2.2 Compaction

Using modified Proctor test the results in table 6.14 are obtained for the mix of demolition debris with different ratio of reclaimed asphalt pavement. The results showed that maximum dry density reduced when reclaimed asphalt pavement rate was 20%. Then dry density increased with increasing reclaimed asphalt pavement, while optimum moisture content has maximum value when reclaimed asphalt pavement ratio was 20% then optimum moisture content decreased with increasing reclaimed asphalt pavement.

Table 6.14 Modified Proctor compaction for Demolition debris with different reclaimed asphalt pavement content.

Material	Max. Dry Density (MDD) ton/m^3	Optimum Water content (OWC)%
R/D 10%	2	11.2
R/D 20%	1.98	13
R/D 30%	2.00	13
R/D 40%	2.03	10.2
R/D 50%	2.04	9.9

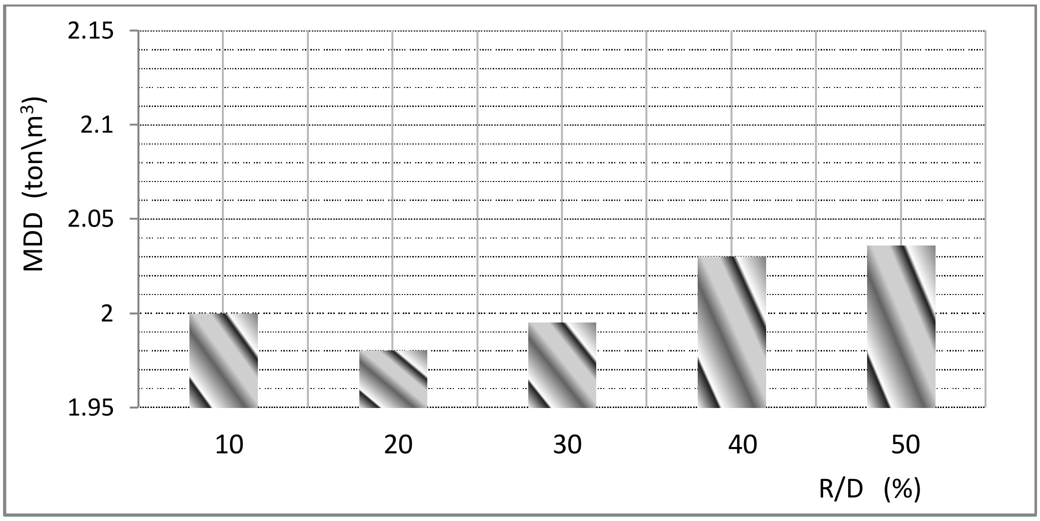

Figure 6.10 Maximum dry density for different R/D

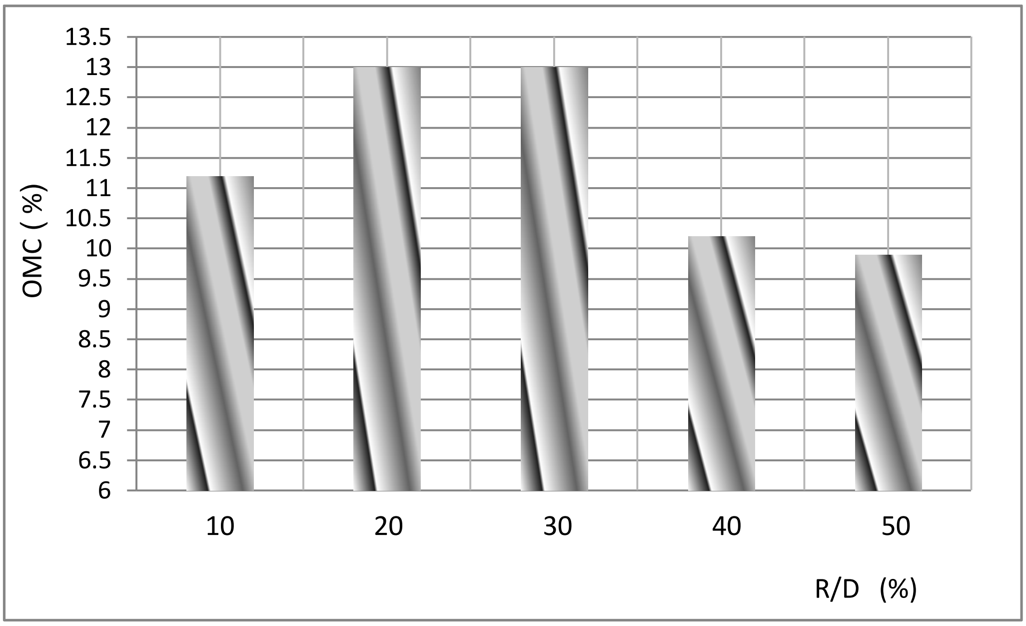

Figure 6.11 Optimum water content for different R/D

6.3.2.3 Atterberg Limits

Table 6.15 shows that no significant changes in liquid limit and all mixes are non-plastic

Table 6.15 Atterberg limits for demolition debris with different reclaimed asphalt pavement content

Material	L.L	P.L	P.I
Demolition debris	22.35	NP	-
R/D 10%	22.75	NP	-
R/D 20%	22.49	NP	-
R/D 30%	21.70	NP	-
R/D 40%	22.82	NP	-
R/D 50%	22.15	NP	-

6.3.2.4 Bulk Specific Gravity SSD and Absorption

Table 6.16 shows that there is no significant changes in bulk specific gravity SSD of fine and coarse aggregate, But absorption decreased in general with increasing in reclaimed asphalt pavement content.

Table 6.16 Bulk specific gravity SSD and Absorption for demolition debris with different reclaimed asphalt pavement content.

Material	Fine Aggregate		Coarse Aggregate	
	Bulk S.G SSD	Absorption	Bulk S.G SSD	Absorption
Demolition debris	2.48	4.80	2.36	5.63
R/D 10%	2.46	4.57	2.38	4.88
R/D 20%	2.42	6.02	2.35	5.65
R/D 30%	2.46	4.15	2.34	4.98
R/D 40%	2.42	4.2	2.38	4.31
R/D 50%	2.5	2.6	2.4	4.46

6.3.2.5 California Bearing Ratio Test

Tests results show that California bearing ratio (CBR) is decreased severely with increasing reclaimed asphalt pavement, with 50% RAP California bearing ration is less than what is required in specification (80%). Table 6.17 and Figure 6.12 show the results.

Table 6.17 CBR for demolition debris with different reclaimed asphalt pavement content

Material	CBR
Demolition debris	277
R/D 10%	117
R/D 20%	107
R/D 30%	125
R/D 40%	109
R/D 50%	77

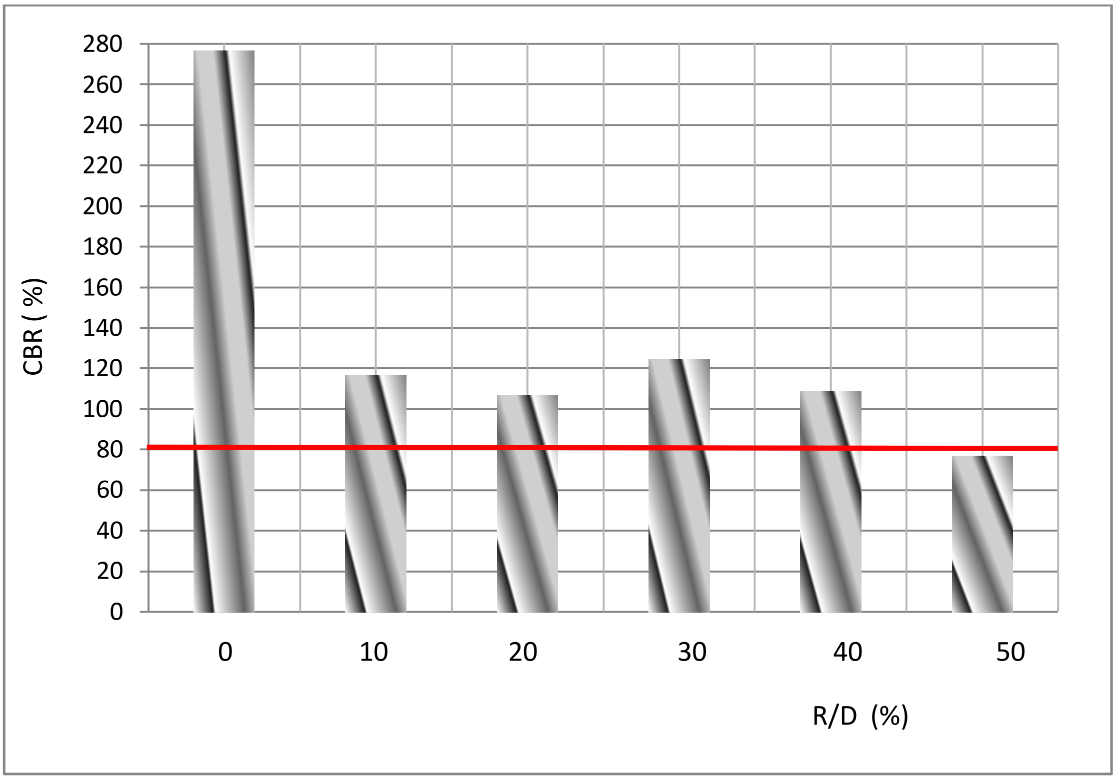

Figure 6.12 CBR for different R/D

6.3.2.6 Sand Equivalent

Tests results shows that the sand equivalent satisfies specifications (greater than 40%) for Demolition debris (As particles that pass sieve size 0.075mm are less than 3 %). After adding reclaimed asphalt pavement with rate until 20% improvement was observed as sand equivalent is raised from 53.9% to 70.49% then a decrease of sand equivalent value is noted with additional adding of reclaimed asphalt pavement as with ratio 50% the sand equivalent reduced to 65.12% but it is still satisfy specifications.

Table 6.18 Sand equivalent for demolition debris with different reclaimed asphalt pavement content

Material	Sand Equivalent
Demolition debris	53.90 %
R/D 10%	65.78 %
R/D 20%	70.49 %
R/D 30%	66.56 %
R/D 40%	65.81 %
R/D 50%	65.12 %

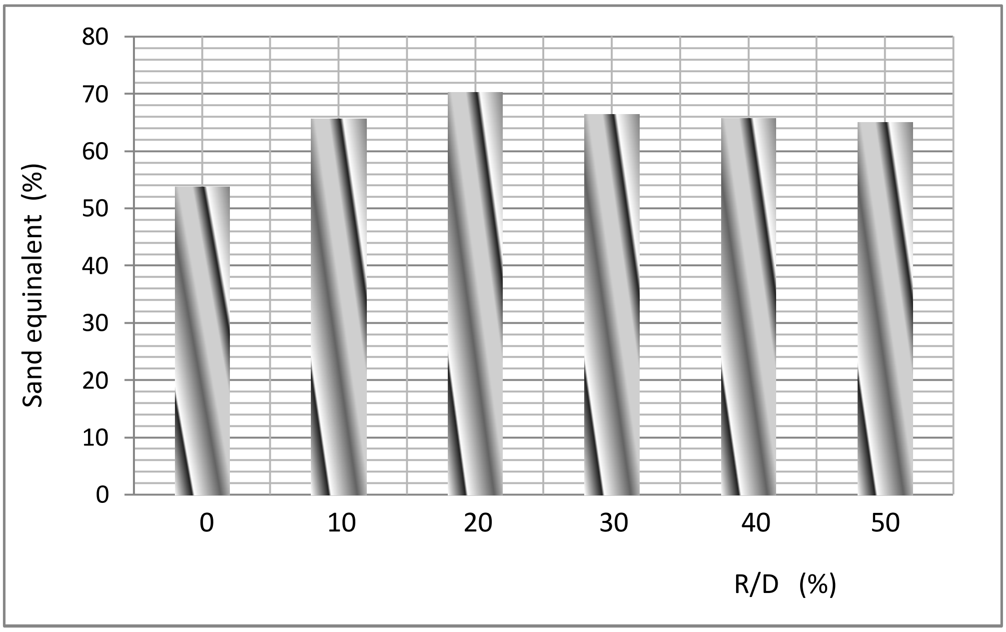

Figure 6.13 Sand equivalent for different R/D

6.3.2.7 Los Angeles Test

Tests results shows that there is significant change and improvement in Los Angeles ratio after mixing RAP as the value decreased from 44.89% for demolition debris to 36.57% for demolition debris mixed with 50% reclaimed asphalt pavement. Table 6.19 and Figure 6.14 shows test results.

Table 6.19 Los Angeles for demolition debris with different reclaimed asphalt pavement content

Material	Los Angeles
Demolition debris	44.89 %
R/D 10%	43.57 %
R/D 20%	40.24 %
R/D 30%	39.00 %
R/D 40%	38.62 %
R/D 50%	36.57 %

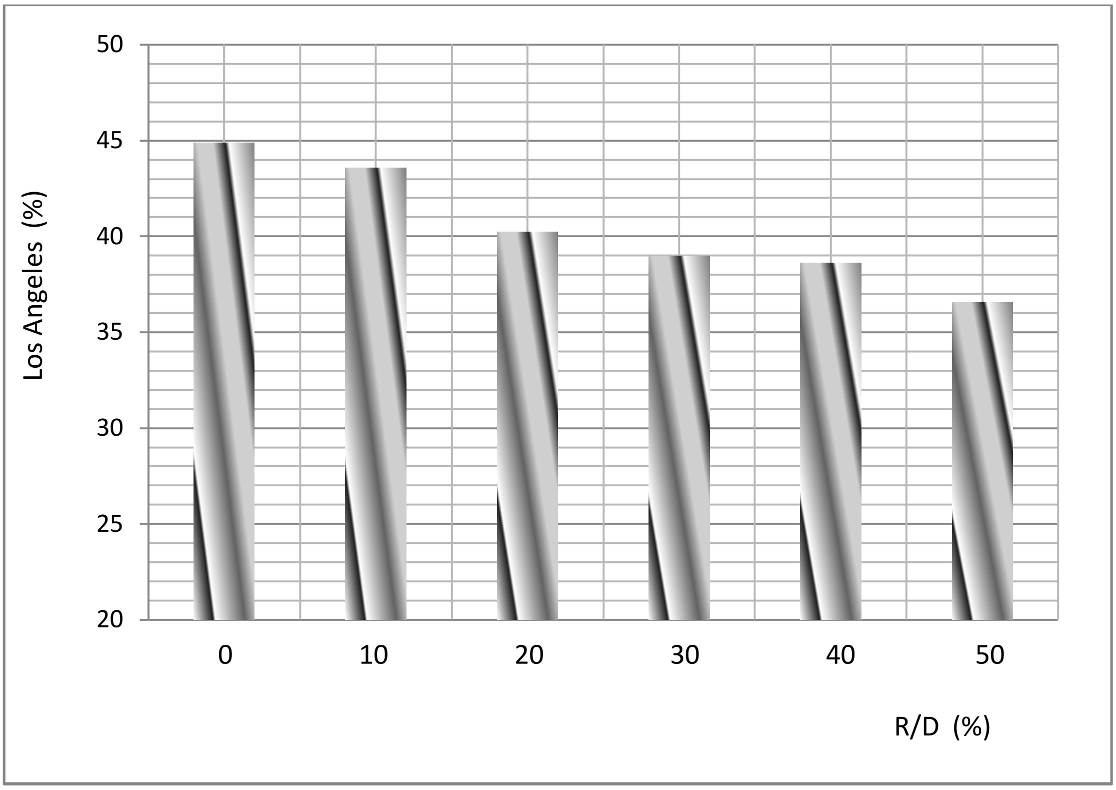

Figure 6.14 Los Angeles ratio for different R/D

6.3.2.8 Results Summary

Table 6.20 summarizes results of adding reclaimed asphalt pavement to demolition debris.

Table 6.20 Results summary for demolition debris with different reclaimed asphalt pavement content.

Test	AASHTO Requirement	D.D	R/D 10%	R/D 20%	R/D 30%	R/D 40%	R/D 50%
Absorption fine	Max 3%	4.80	4.57	6.02	4.15	4.20	2.60
Absorption course	Max 3%	5.63	4.88	5.65	4.98	4.31	4.46
Bulk S.G SSD fine	2.6	2.48	2.46	2.42	2.46	2.42	2.50
Bulk S.G SSD course	2.6	2.366	2.38	2.35	2.34	2.38	2.40
L.L	Max 25%	22.35	22.75	22.49	21.70	22.82	22.15
P.L		N.P	N.P	N.P	N.P	N.P	N.P
P.I	Max 6%	-	-	-	-	-	-
Max dry density		1.99	2.00	1.98	1.995	2.03	2.04
Optimum water		9.00	11.20	13.00	13.00	10.20	9.90
CBR	Min 80%	306	117	99	126	109	77
Los Angeles	Max 45%	44.89	43.57	40.24	39.00	38.62	36.57
Sand equivalent	Min 40%	53.90	65.78	70.49	66.56	65.81	65.12

6.3.3 Comparing Conventional Material and Demolition Debris After Adding Reclaimed Asphalt Pavement

Figure 6.15 shows that after adding reclaimed asphalt pavement the maximum dry density decreased for conventional material because dry density of RAP is less than dry density for conventional material.

While dry density increased for demolition debris with adding RAP as the dry density of RAP is greater than dry density of demolition debris..

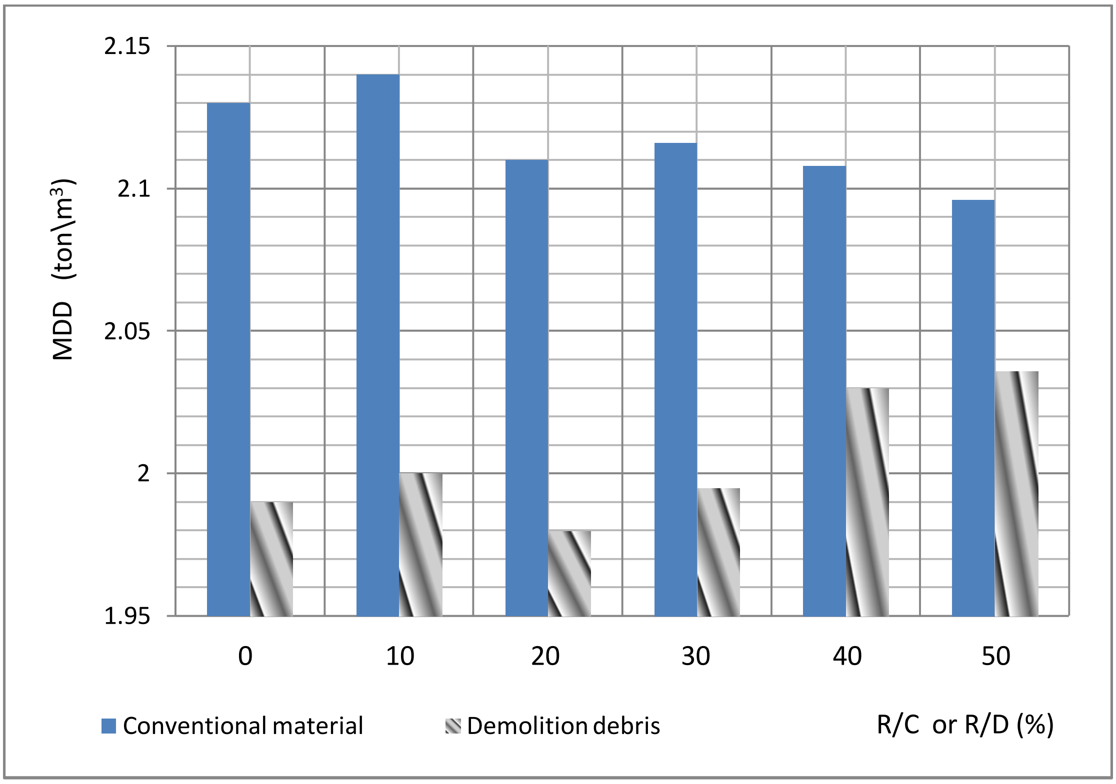

Figure 6.15 Maximum dry density for conventional material and demolition debris with different R/C and R/D

Figure 6.16 shows optimum moisture content after adding reclaimed asphalt pavement to conventional material and to demolition debris. Optimum moisture content for demolition debris is high due to the existence of cements mortar, lime and other suspension materials which absorb water.

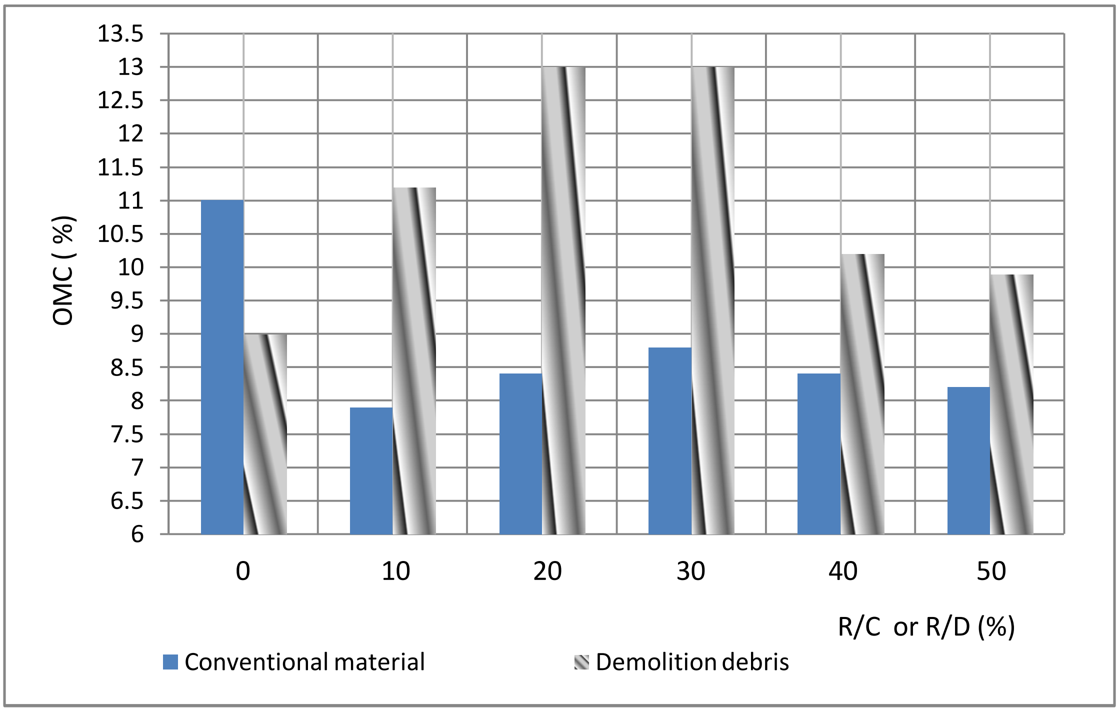

Figure 6.16 Optimum moisture content for conventional material and demolition debris with different R/C and R/D

Figure 6.17 shows CBR value after adding reclaimed asphalt pavement for conventional material and for demolition debris. Generally CBR value decreased with increasing RAP content, which caused by decrease particle angularity.

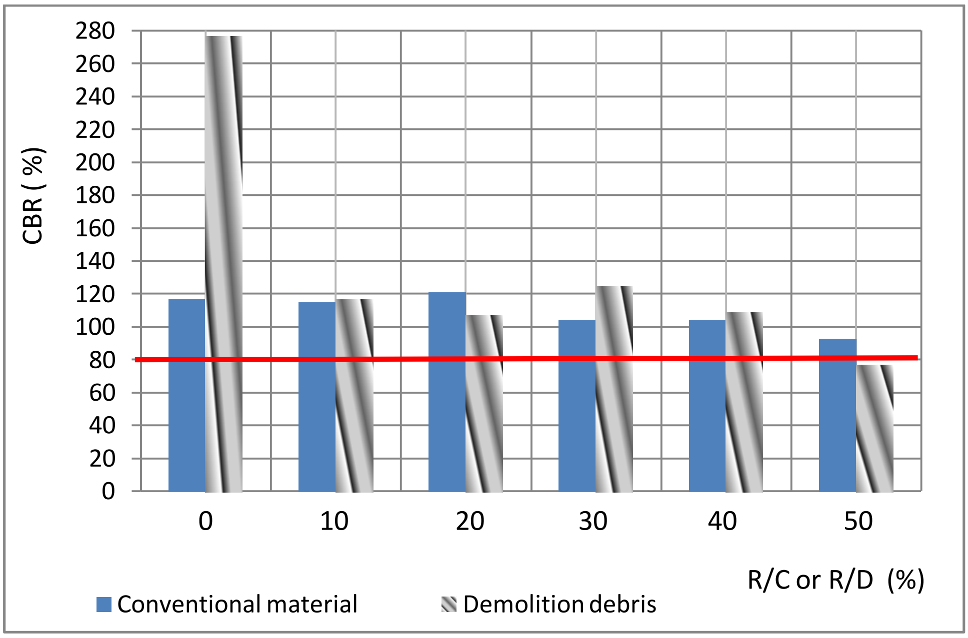

Figure 6.17 CBR for conventional material and demolition debris with different R/C and R/D

Figure 6.18 shows sand equivalent after adding reclaimed asphalt pavement for conventional material and for demolition debris. Sand equivalent improved with adding RAP because RAP had lower percentage of fines.

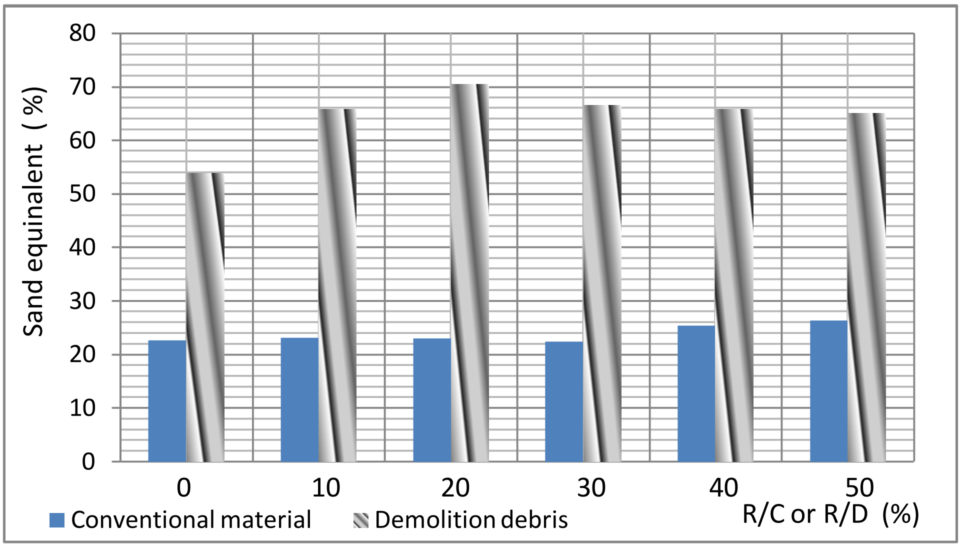

Figure 6.18 Sand equivalent for conventional material and demolition debris with different R/C and R/D

Figure 6.19 shows Los Angeles after adding reclaimed asphalt pavement for demolition debris. Los Angeles value improved with increasing RAP that because RAP aggregates is more stiff than conventional and demolition debris aggregate. But for adding RAP to conventional material no significant changes in los Angeles value.

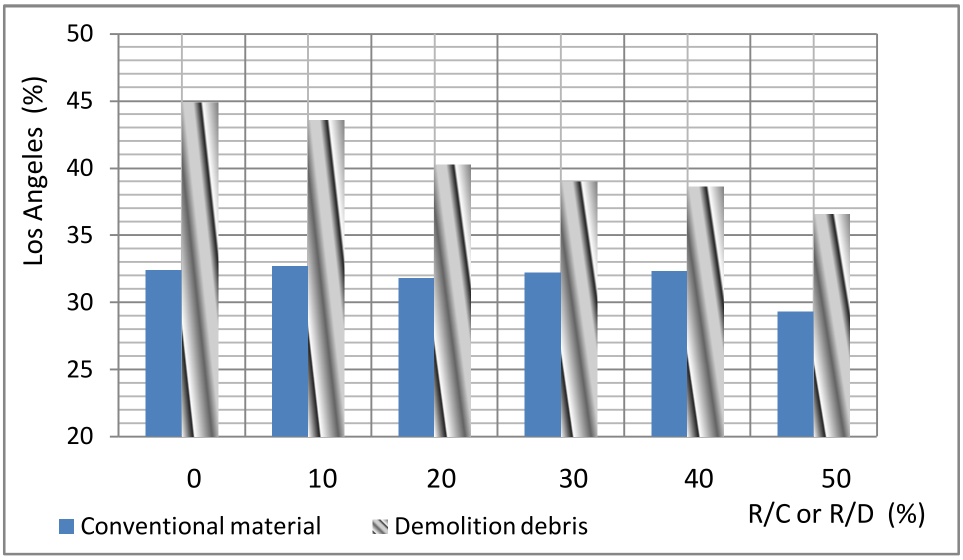

Figure 6.19 Los Angeles for conventional material and demolition debris with different R/C and R/D

6.4 Conclusion

From comparing results it is noted that CBR value is critical point specially for adding reclaimed asphalt pavement to demolition debris. Demolition debris has very high CBR value, as the existence of cement between demolition debris particles increase its ability to penetration resistance. After adding reclaimed asphalt pavement with particles coated with asphalt which increase ability of compression and so decrease penetration resistance.

Gradation is another important factor, as with increasing RAP content in demolition debris the mix becomes more coarse and the curve is more closed to lower limits of AASHTO specifications.

Chapter Seven: Conclusions and Recommendations

7.1 Conclusions

In this research the properties of demolition debris mixed with different ratios of reclaimed asphalt pavement were tested and 40% of RAP is the maximum ratio recommended. Conventional materials mixed with different ratios of reclaimed asphalt pavement were tested too, and 50% RAP content is valid for Gaza Strip conditions. and materials available in local markets.

A testing program was conducted including CBR, Los Angeles, sieve analysis, specific gravity, absorption and sand equivalent. It is noted that samples passed these tests requirement for different ratios of reclaimed asphalt pavement, but CBR value decreased with increasing reclaimed asphalt pavement content although it still satisfy AASHTO specifications.

In other hand adding reclaimed asphalt pavement improving Los Angeles values, absorption ratio and sand equivalent. Sieve analysis shows that by adding reclaimed asphalt pavement after removing particles greater than 50mm the curve satisfy specifications, as AASHTO specifications indicate that no particles return on sieve 50mm.

After adding reclaimed asphalt pavement with different contents to demolition debris. It is noted that demolition debris generally has low bulk specific gravity (SSD), and adding reclaimed asphalt pavement has no significant effect on bulk specific gravity. Demolition debris has high value of absorption which is improved with adding reclaimed asphalt pavement. CBR values are very sensitive to adding reclaimed asphalt pavement as it decreased from 277% for demolition debris to 77% for R/D 50%. This means that reclaimed asphalt pavement must not be increased more than 40% to satisfy specifications (CBR 80%). Los Angeles results showed that it is improved with adding more reclaimed asphalt pavement.

7.2 Recommendations

1. The reclaimed asphalt pavement shouldn't be more than 40% in the demolition debris when it used as aggregate for base course.
2. The reclaimed asphalt pavement content 50% in conventional materials is suitable for Gaza condition as a maximum ratio.
3. Crushers have to produce crushed aggregates with gradation (0/50)mm.
4. Crushers have to improve method for removing non- accepted material as wood, plastic, and nylons.
5. It is recommended to produce aggregates with separate sieves particle as Folia (0/19.5)mm, Adasia (0/12.5)mm and Semsemia (0/9.5)mm.
6. It is required to establish local specifications for Palestine.
7. It is recommended to execute governmental monitoring on local crushers.
8. Recycled material is considered a good alternative of conventional base course.
9. It is recommended to establish permanent recycling facilities in Gaza due to high quantities available due to political situations and urbanization.
10. Further studies should be done on recycling material in Gaza to improve environmental situation and solving material shortage problem in local market.

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Appendix (A)
Results

a.1 Conventional material:

a.1.1 Gradation

Table A.1 shows results of sieve analysis test of conventional material:

Wt. passing #4 : B	3908.6
Wt. retauned on #4	6480
Wt. mixed sample : A	10388.6
wt. small sample passing #4 befor washing: C	1012.3

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	0			10388.6		100.00
37.5	950			9438.6		90.86
25	1245			8193.6		78.87
19	955			7238.6		69.68
12.5	1265			5973.6		57.50
9.5	750			5223.6		50.28
4.75	1315			3908.6		37.62
2		301.7	710.6		70.20	26.41
1.18		139.4	571.2		56.43	21.23
0.6		116.2	455		44.95	16.91
0.425		46.4	408.6		40.36	15.19
0.3		32.6	376		37.14	13.97
0.15		61.2	314.8		31.10	11.70
0.075		47.2	267.6		26.43	9.95

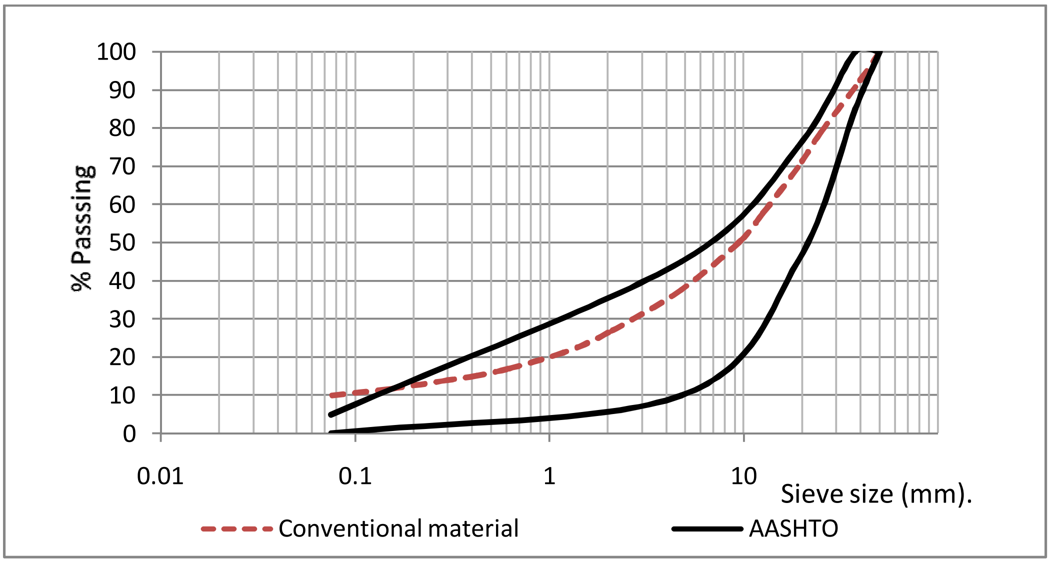

Figure A.1 Conventional material gradation.

a.1.2 Atterberg limits

Table A.2 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for conventional material.

Plastic limit	
Can no	C7
Wt. of can	47.95
wt. wet soil and can	63.86
wt. dry soil amd can	61.51
water wt.	2.35
dry wt.	13.56
water content	17.33
Plastic limit	17%

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penetrations
c11	25.19	79.74	70.14	9.6	44.95	21.36	24.1
c30	28.53	123.26	107.15	16.11	78.62	20.49	19.7
c16	24.82	133.41	115.35	18.06	90.53	19.95	16.7
At penetration 20mm water content 20.55							
L.L = 20.55%							

Plastic Index	3.55%

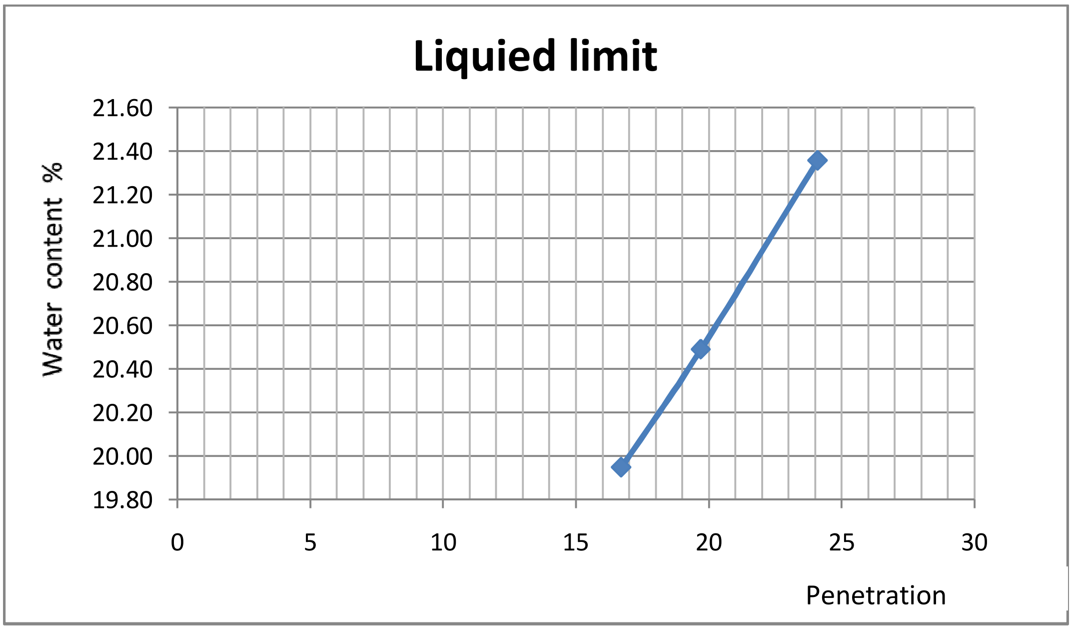

Figure A.2 Conventional material Liquid limit

a.1.3 California bearing ratio

Table A.3 shows results of CBR for conventional material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.272	61.15	20.38
1	0.039	0.603	135.57	45.19
1.5	0.059	1.089	244.83	81.61
2	0.079	1.770	397.93	132.65
2.5	0.098	2.680	602.52	200.84
3	0.118	3.730	838.58	279.53
4	0.157	7.070	1589.48	529.84
5	0.197	12.000	2697.84	899.30
6	0.236	15.920	3579.14	1193.07
7.5	0.295	24.290	5460.88	1820.33
9	0.354	30.500	6857.01	2285.71

CBR 0 .1	85
CBR 0.2	116.67
Take CBR	117%

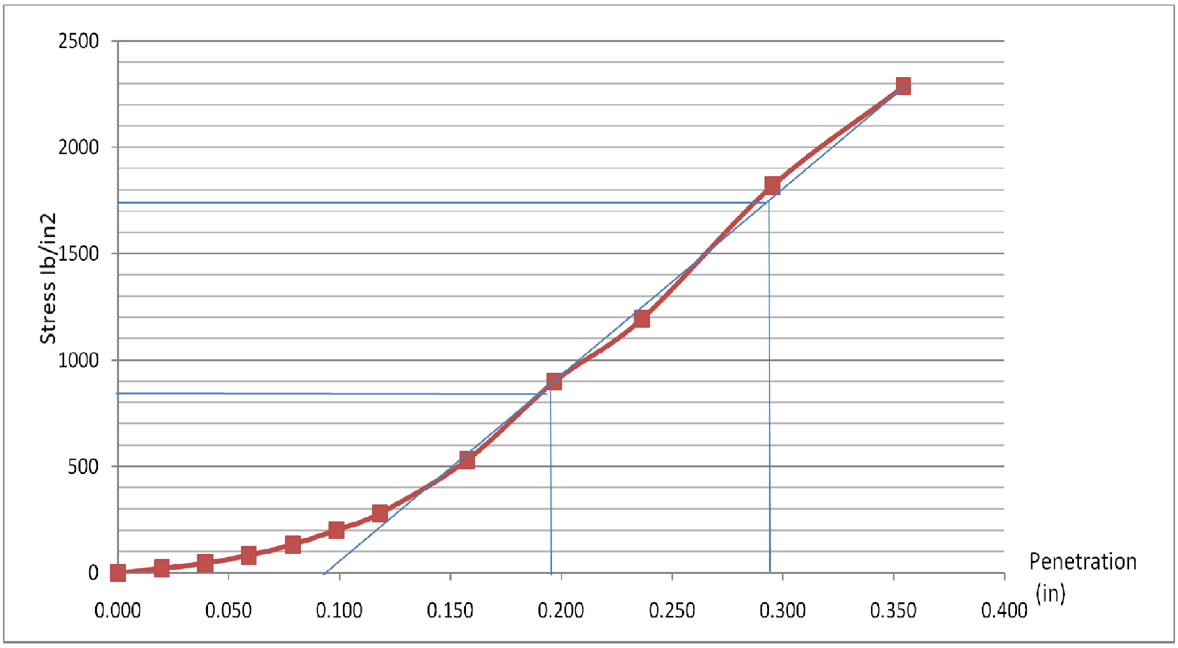

Figure A.3 Conventional material CBR

a.1.4 Modified Proctor

Table A.4 shows results of modified proctor compaction test for conventional material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
F14	115	576	544.2	7.41
P1	98.42	422.21	391.62	10.43
F4	97	422	385.57	12.62
V3	103.5	535.5	479.84	14.79

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4919.5	9292.5	4373	2.06	1.92
4919.5	9901.5	4982	2.35	2.12
4919.5	9932.5	5013	2.36	2.10
4919.5	9919.5	5000	2.35	2.05

mold volume	2123.7635
Pd max	2.13
W	11%

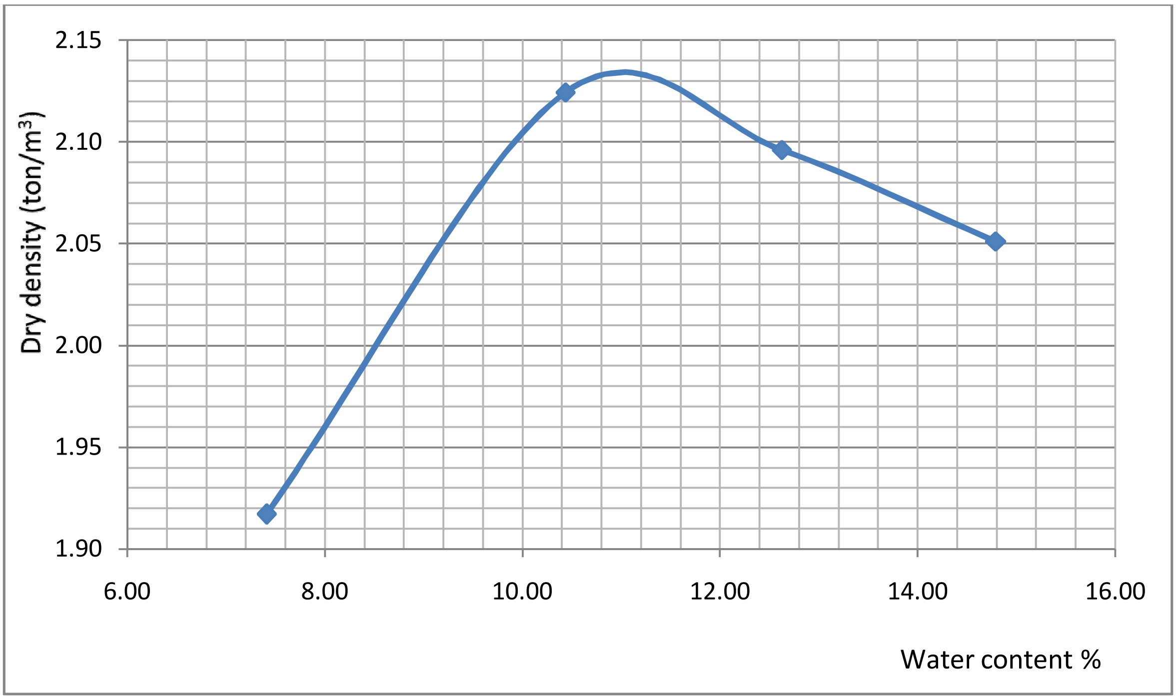

Figure A.4 Conventional material Proctor test

a.1.5 Specific gravity and Absorption

Table A.5 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of conventional material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2020.24
dry wt.	1912.44
SSD supmerged	1193.17
Bulk specific gravity	2.31
Bulk specific gravity (SSD)	2.44
Apparent Specific gravity	2.66
Absorption	5.64%

Specific gravity & Absorption of fine aggregates	
Can wt.	101.78
dry wt. and can wt.	558.03
dry wt.	456.25
SSD wt.	483.33
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2083.61
Bulk specific gravity	2.46
Bulk specific gravity (SSD)	2.60
Apparent Specific gravity	2.87

a.1.6 Sand equivalent and Absorption

Table A.6 shows results of Sand equivalent for conventional material.

	Sample 1	Sample 2
Sand reading	72	80
Clay reading	333	338
Sand equivalent	21.60%	23.70%
Avarage Sand equivalent		22.70%

a.1.7 Los Angeles test

Table A.7 shows results of Los Angeles test for conventional material.

wt. of sample (g)	5000
wt. of losses (g)	1620
Los Angeles ratio	32.40%

a.2 Demolition Debris:

a.2.1 Gradation

Table A.1 shows results of sieve analysis test of Demolition debris:

Wt. passing #4 : B	2442
Wt. mixed sample : A	10055.5
wt. small sample passing #4 befor washing: C	1152

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	0			10055.5		100.00
37.5	634			9421.5		93.69
25	1831.5			7590		75.48
19	1395			6195		61.61
12.5	2009			4186		41.63
9.5	623			3563		35.43
4.75	1032.5			2530.5		25.17
2		189.5	962.5		83.55	20.29
1.18		75	887.5		77.04	18.71
0.6		107.5	780		67.71	16.44
0.425		124	656		56.94	13.83
0.3		167	489		42.45	10.31
0.15		297.5	191.5		16.62	4.04
0.075		55.5	136		11.81	2.87

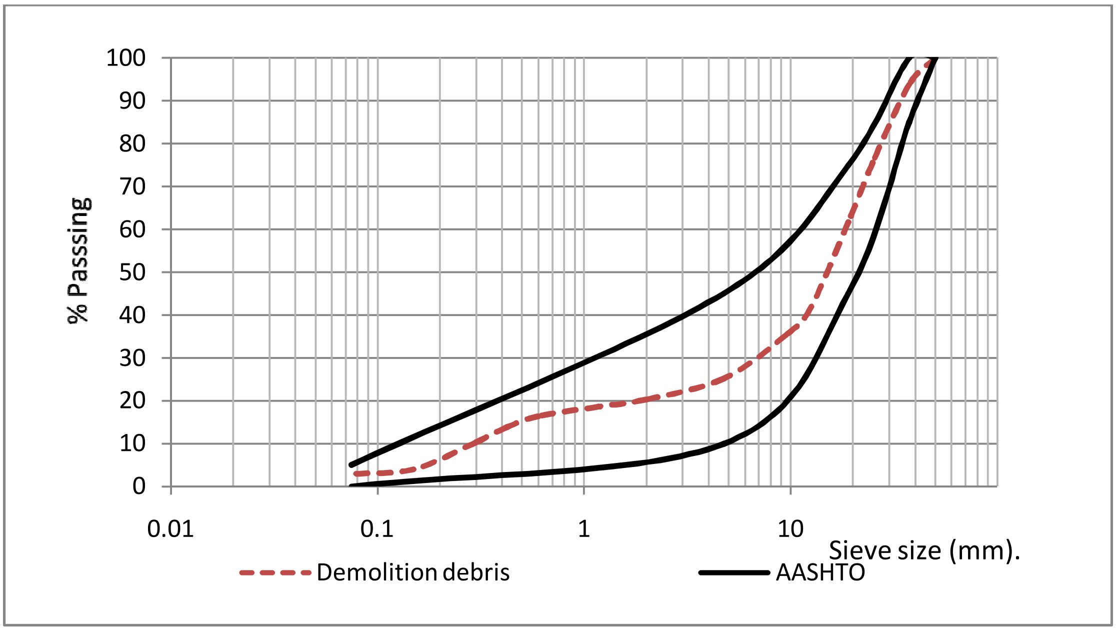

Figure A.5 Demolition debris gradation.

a.2.2 Atterberg limits

Table A.2 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for Demolition debris.

Plastic limit	
Plastic limit	Non-Plastic

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
x65	35.31	69.36	62.8	6.56	27.49	23.86	23.1
c3	47.61	97.53	88.46	9.07	40.85	22.20	19.3
c25	26.8	73.49	65.15	8.34	38.35	21.75	15.9
At penetration 20mm water content 22.35							
L.L = 22.35%							

Plastic Index	-

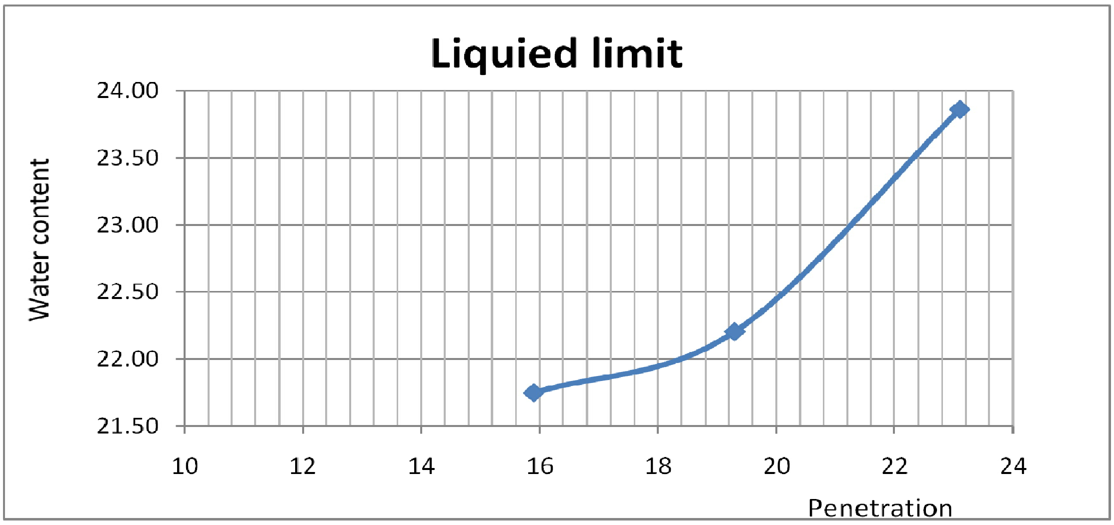

Figure A.6 Demolition debris Liquid limit

a.2.3 California bearing ratio

Table A.3 shows results of CBR for Demolition debris

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	1.050	236.06	78.69
1	0.039	2.130	478.87	159.63
1.5	0.059	3.450	775.63	258.55
2	0.079	5.220	1173.56	391.19
2.5	0.098	8.150	1832.28	610.77
3	0.118	12.420	2792.27	930.77
4	0.157	23.900	5373.20	1791.10
5	0.197	36.200	8138.49	2712.88

CBR 0 .1	205
CBR 0.2	276.67
Take CBR	277 %

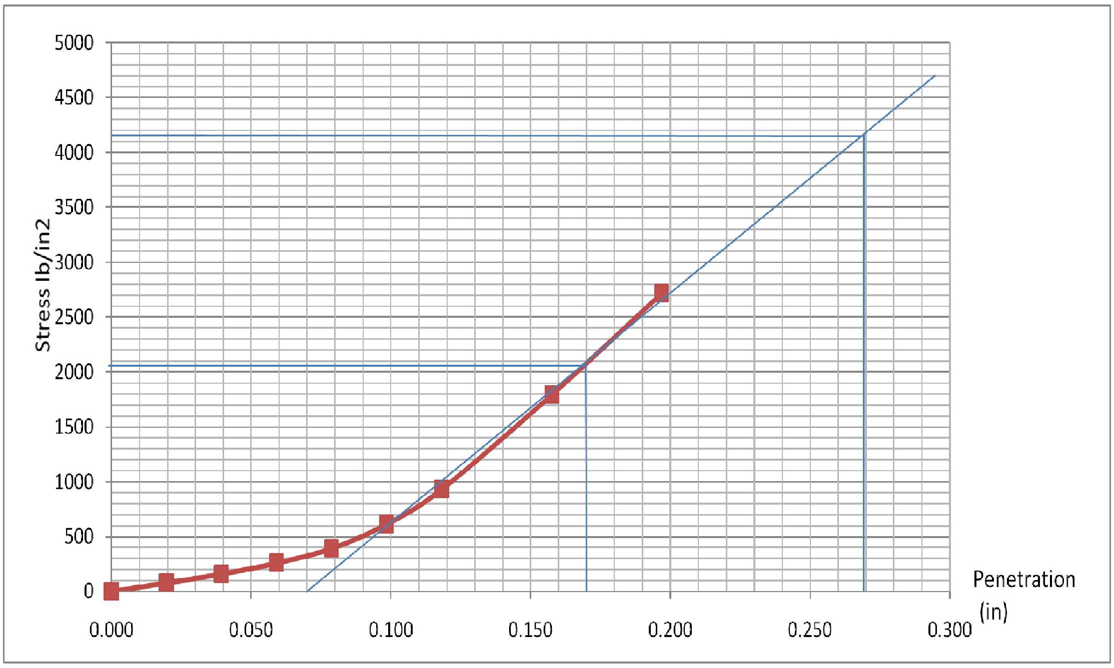

Figure A.7 Demolition debris CBR

a.2.4 Modified Proctor

Table A.4 shows results of modified proctor compaction test for Demolition debris

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
F300	117.66	736.86	713.83	3.86
F10	107.54	629.26	596.72	6.65
U4	102.66	612.86	574.94	8.03
F1	91.62	785.87	720.45	10.40
F14	115.6	795.51	716.31	13.18

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4921.5	9050.5	4129	1.94	1.872
4921.5	9264	4342.5	2.04	1.917
4921.5	9473	4551.5	2.14	1.984
4921.5	9564.5	4643	2.19	1.980
4921.5	9546.5	4625	2.18	1.924

mold volume	2123.7635
Pd max	1.99
W	9%

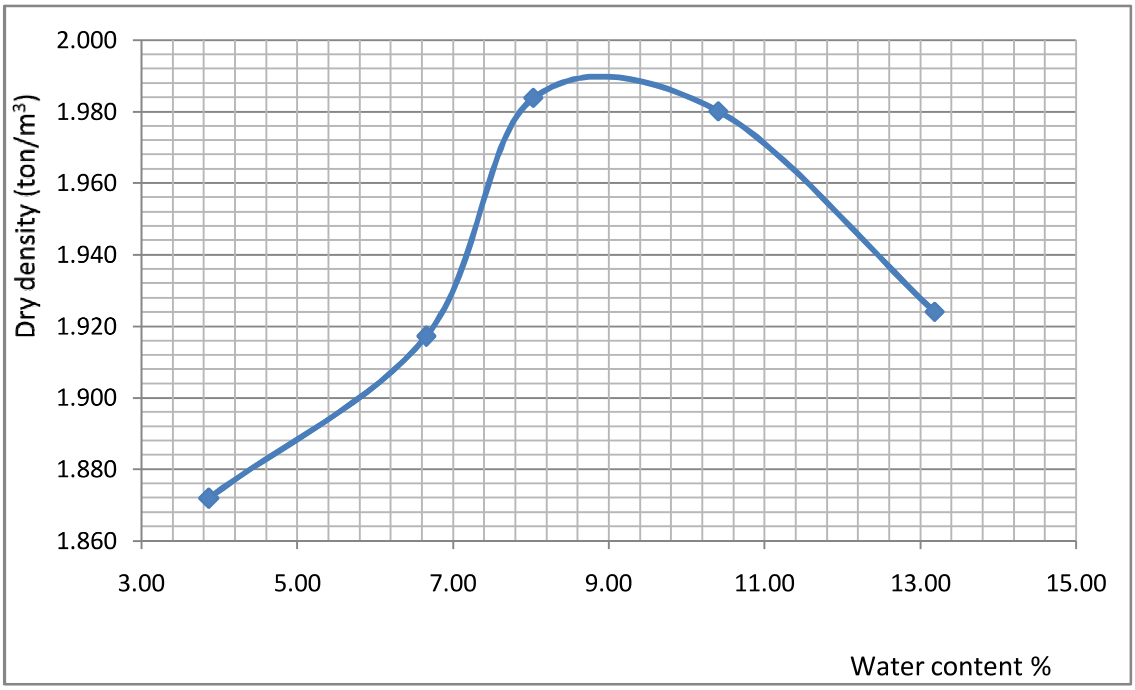

Figure A.8 Demolition debris Proctor test

a.2.5 Specific gravity and Absorption

Table A.5 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of Demolition debris.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2074.26
dry wt.	1963.63
SSD supmerged	1195.59
Bulk specific gravity	2.23
Bulk specific gravity (SSD)	2.36
Apparent Specific gravity	2.56
Absorption	5.63%

Specific gravity & Absorption of fine aggregates	
Can wt.	82.54
dry wt. and can wt.	463.34
dry wt.	380.8
SSD wt.	399.08
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2024.18
Bulk specific gravity	2.37
Bulk specific gravity (SSD)	2.48
Apparent Specific gravity	2.67

a.2.6 Sand equivalent and Absorption

Table A.6 shows results of Sand equivalent for Demolition debris.

	Sample 1	Sample 2
Sand reading	110	100
Clay reading	220	173
Sand equivalent	50.00%	57.80%
Avarage Sand equivalent		53.90%

a.2.7 Los Angeles test

Table A.7 shows results of Los Angeles test for Demolition debris.

wt. of sample (g)	5000
wt. of losses (g)	2244.5
Los Angeles ratio	44.89%

a.3 R/C 10% material:

a.3.1 Gradation

Table A.1 shows results of sieve analysis test of R/C 10% material:

Wt. passing #4 : B	5606.73
Wt. retauned on #4	11225
Wt. mixed sample : A	16831.73
wt. small sample passing #4 befor washing: C	974.07

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	0			16831.73		100.00
37.5	1700			15131.73		89.90
25	2865			12266.73		72.88
19	1340			10926.73		64.92
12.5	2260			8666.73		51.49
9.5	1090			7576.73		45.01
4.75	1970			5606.73		33.31
2		279.77	694.3		71.28	23.74
1.18		141.46	552.84		56.76	18.91
0.6		120.59	432.25		44.38	14.78
0.425		48.4	383.85		39.41	13.13
0.3		79.41	304.44		31.25	10.41
0.15		46.09	258.35		26.52	8.83
0.075		11.59	246.76		25.33	8.44

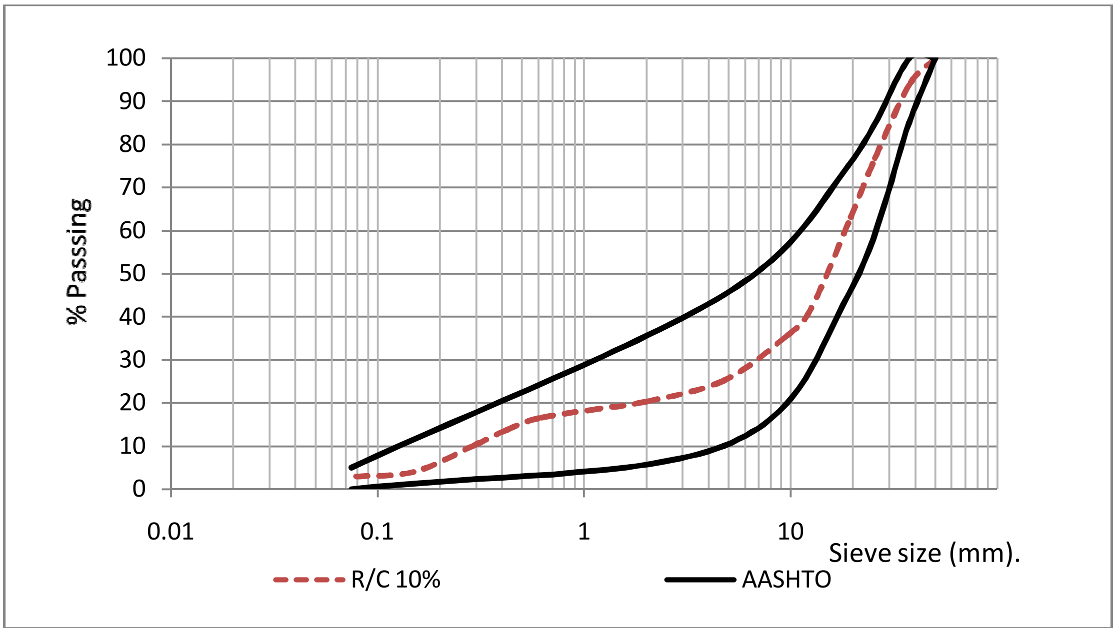

Figure A.9 R/C 10% material gradation.

a.3.2 Atterberg limits

Table A.2 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/C 10% material.

Plastic limit	
Can no	R-9
Wt. of can	136.43
wt. wet soil and can	156.08
wt. dry soil amd can	153.3
water wt.	2.78
dry wt.	16.87
water content	16.48
Plastic limit	16.5%

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
X-2	156.91	191.77	185.8	5.97	28.89	20.66	17.8
R-7	147.95	188.07	181.03	7.04	33.08	21.28	19
R-4	151.68	206.15	196.18	9.97	44.5	22.40	22.8
At penetration 20mm water content 21.6							
L.L = 21.60%							

Plastic Index	5.10%

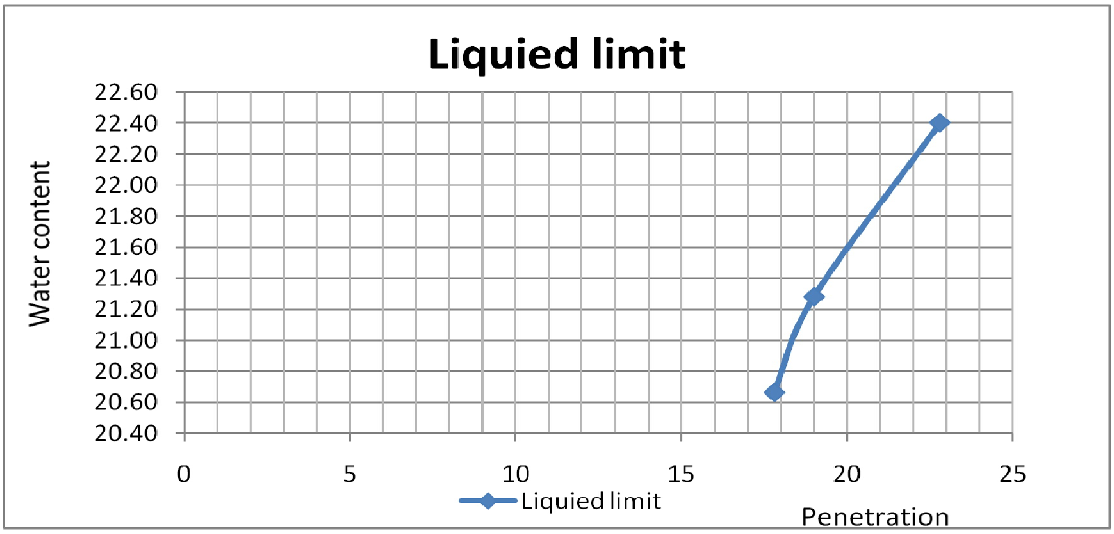

Figure A.10 R/C 10% material Liquid limit

a.3.3 California bearing ratio

Table A.3 shows results of CBR for R/C 10% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.660	148.38	49.46
1	0.039	1.490	334.98	111.66
1.5	0.059	2.710	609.26	203.09
2	0.079	4.220	948.74	316.25
2.5	0.098	5.930	1333.18	444.40
3	0.118	7.740	1740.11	580.05
4	0.157	12.000	2697.84	899.30
5.022	0.198	16.747	3765.06	1255.04
0	0.000	0.000	0	0
0.5	0.020	0.660	148.38	49.46
1	0.039	1.490	334.98	111.66

CBR 0 .1	86
CBR 0.2	114.67
Take CBR	115%

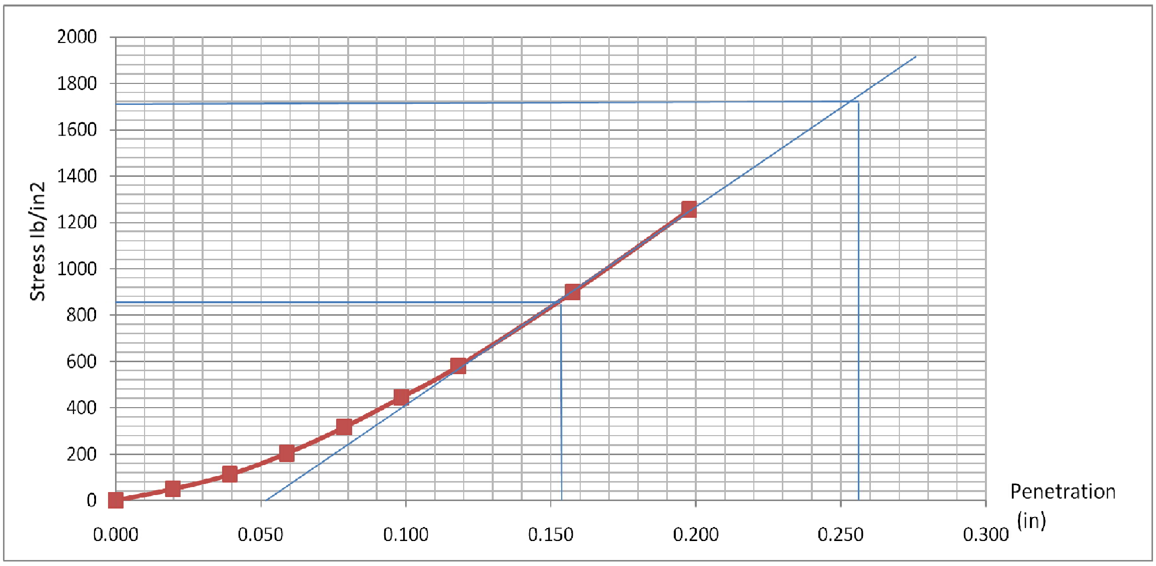

Figure A.11 R/C 10% material CBR

a.3.4 Modified Proctor

Table A.4 shows results of modified proctor compaction test for R/C 10% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
Z27	111.04	613.44	582.69	6.52
Q11	113.51	535.85	504.98	7.89
M4	95.72	562.49	516.8	10.85

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
5200	9820	4620	2.18	2.042
5200	10110	4910	2.31	2.143
5200	10080	4880	2.30	2.073

mold volume	2123.76
Pd max	2.14
W	0.08

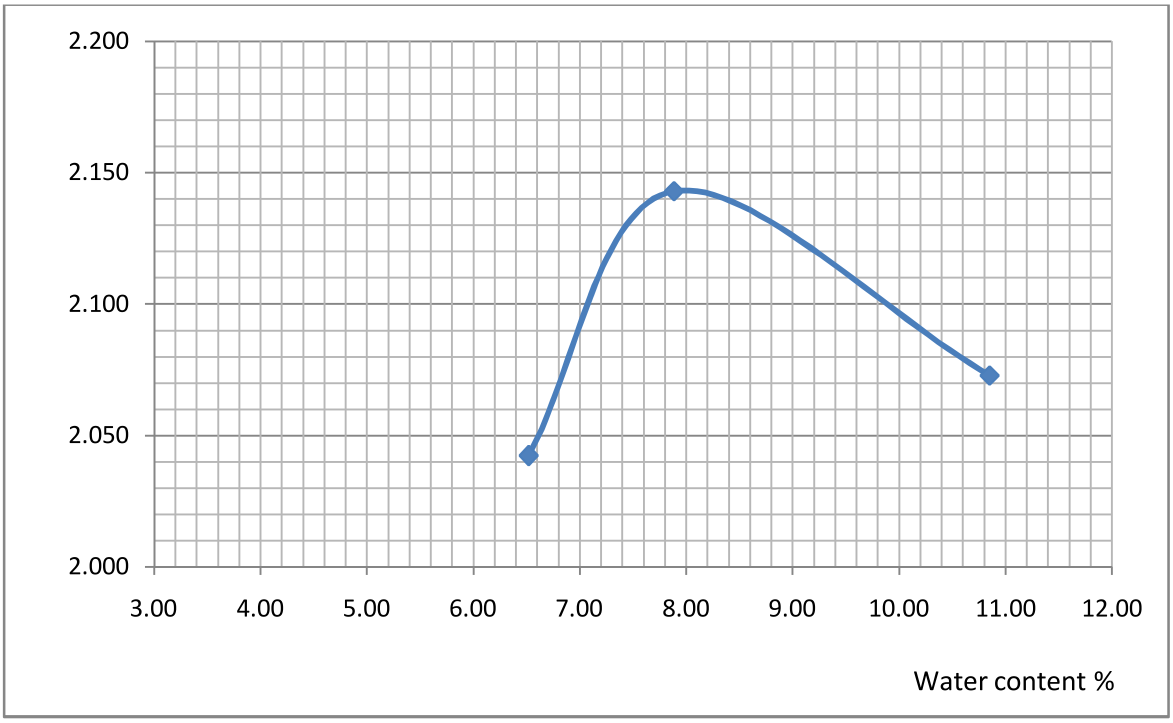

Figure A.12 R/C 10% material Proctor test

a.3.5 Specific gravity and Absorption

Table A.5 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/C 10% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2002.04
dry wt.	1924.48
SSD supmerged	1187.1
Bulk specific gravity	2.36
Bulk specific gravity (SSD)	2.46
Apparent Specific gravity	2.61
Absorption	4.03%

Specific gravity & Absorption of fine aggregates	
Can wt.	105.37
dry wt. and can wt.	487.18
dry wt.	381.81
SSD wt.	399.99
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2029.86
Bulk specific gravity	2.44
Bulk specific gravity (SSD)	2.56
Apparent Specific gravity	2.77

a.3.6 Sand equivalent and Absorption

Table A.6 shows results of Sand equivalent for R/C 10% material.

	Sample 1	Sample 2
Sand reading	78	72.5
Clay reading	325	325
Sand equivalent	24.00%	22.31%
Avarage Sand equivalent		23.15%

a.3.7 Los Angeles test

Table A.7 shows results of Los Angeles test for R/C 10% material.

wt. of sample (g)	5000
wt. of losses (g)	1635
Los Angeles ratio	32.70%

a.4 R/C 20% material:

a.4.1 Gradation

Table A.22 shows results of sieve analysis test of R/C 20% material:

Wt. passing #4 : B	5914.19
Wt. retauned on #4	12665
Wt. mixed sample : A	18579.19
wt. small sample passing #4 befor washing: C	977.79

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	460			18119.19		97.52
37.5	1775			16344.19		87.97
25	2460			13884.19		74.73
19	1565			12319.19		66.31
12.5	2725			9594.19		51.64
9.5	1400			8194.19		44.10
4.75	2280			5914.19		31.83
2		310.58	667.21		68.24	21.72
1.18		142.32	524.89		53.68	17.09
0.6		115.63	409.26		41.86	13.32
0.425		42.62	366.64		37.50	11.94
0.3		42.44	324.2		33.16	10.55
0.15		61.52	262.68		26.86	8.55
0.075		25.68	237		24.24	7.72

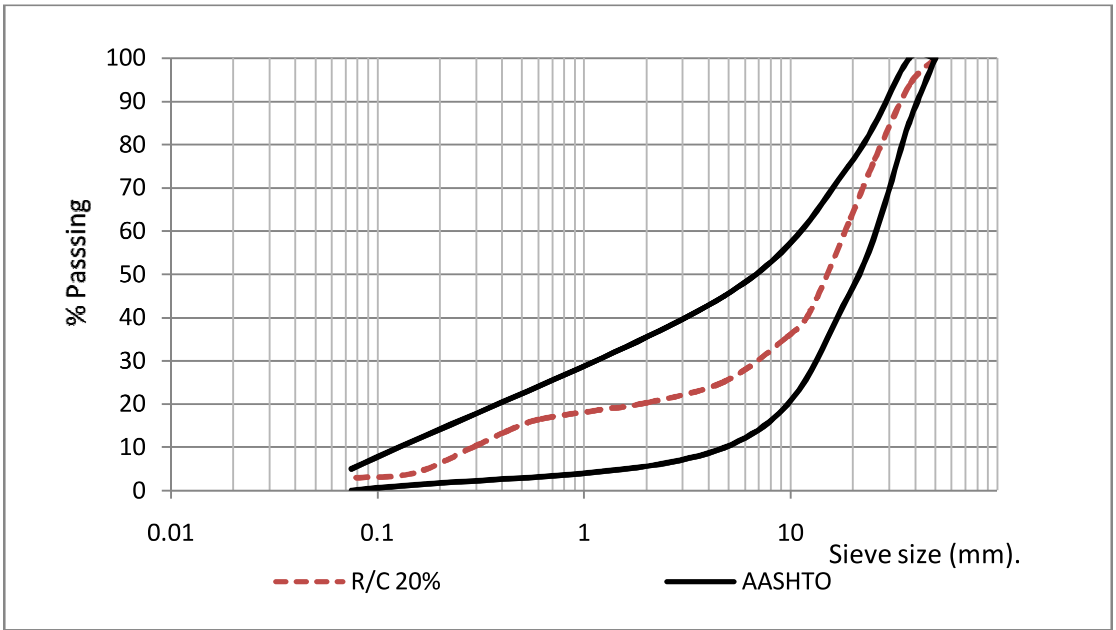

Figure A.13 R/C 20% material gradation.

a.4.2 Atterberg limits

Table A.23 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/C 20% material.

Plastic limit	
Can no	A-14
Wt. of can	140.97
wt. wet soil and can	156.15
wt. dry soil amd can	154.39
water wt.	1.76
dry wt.	13.42
water content	13.11
Plastic limit	13.1%

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
R-6	161	211.32	202.28	9.04	41.28	21.90	20.5
R-11	146.38	184.61	177.81	6.8	31.43	21.64	18.2
At penetration 20mm water content 21.84							
L.L = 21.80%							

Plastic Index	8.70 %

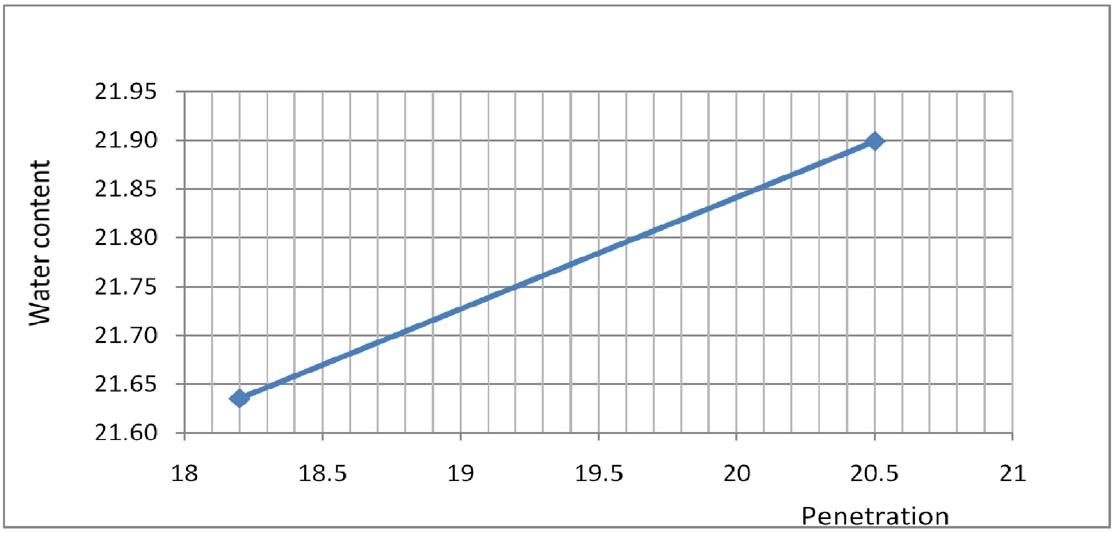

Figure A.14 R/C 20% material Liquid limit

a.4.3 California bearing ratio

Table A.24 shows results of CBR for R/C 20% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.830	186.60	62.20
1	0.039	1.990	447.39	149.13
1.5	0.059	3.730	838.58	279.53
2	0.079	5.820	1308.45	436.16
2.5	0.098	8.210	1845.77	615.27
3	0.118	10.600	2383.09	794.38
4	0.157	15.830	3558.90	1186.32
4.376	0.172	17.862	4015.74	1338.60

CBR 0 .1	90
CBR 0.2	121.33
Take CBR	121%

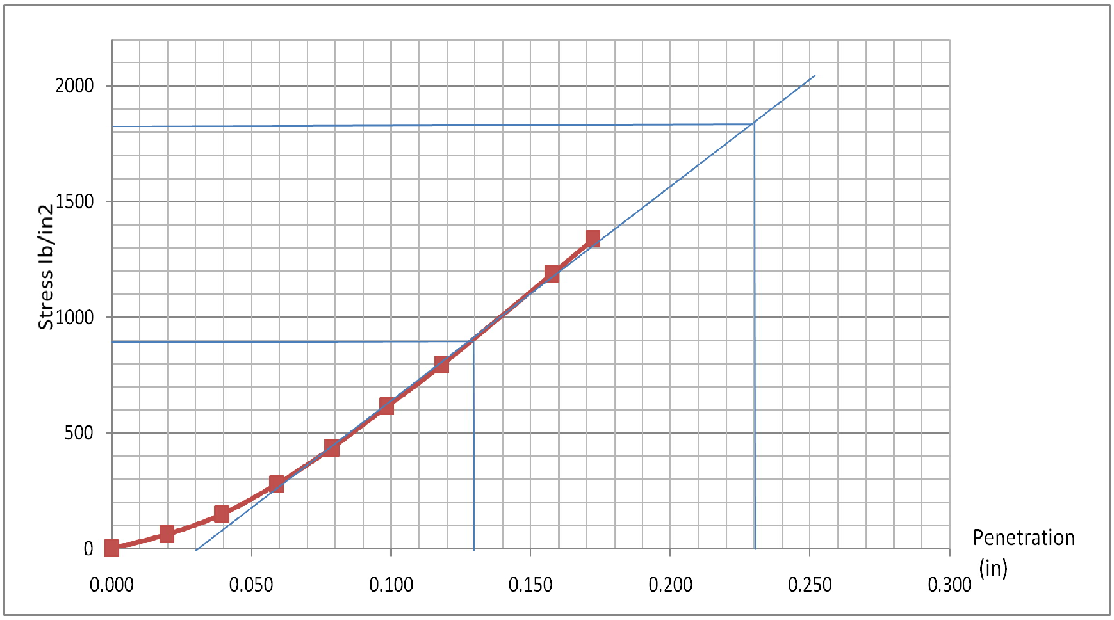

Figure A.15 R/C 20% material CBR

a.4.4 Modified Proctor

Table A.25 shows results of modified proctor compaction test for R/C 20% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
F1	91.62	568.1	550.79	3.77
F14	115.64	470.1	446.26	7.21
F10	112.59	557.26	521.07	8.86
P4	92.67	539.2	489.26	12.59

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
5200	9525	4325	2.04	1.962
5200	9925	4725	2.22	2.075
5200	10070	4870	2.29	2.106
5200	9995	4795	2.26	2.005

mold volume	2123.7635
Pd max	2.11
W	8.4%

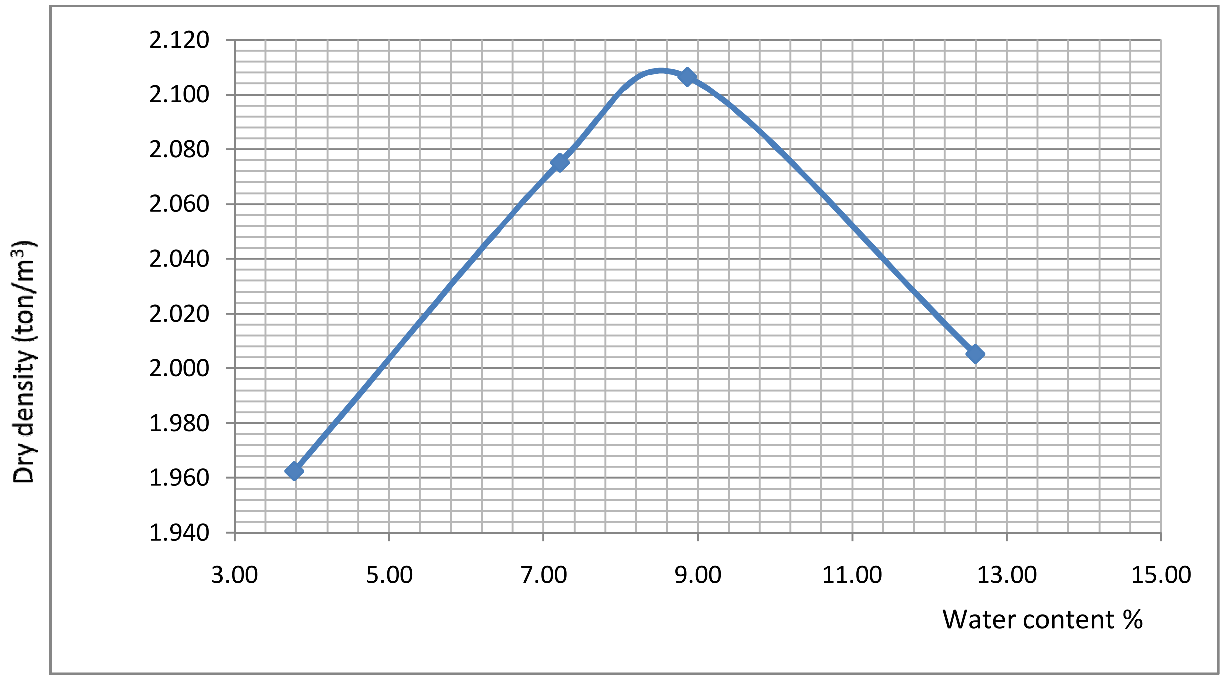

Figure A.16 R/C 20% material Proctor test

a.4.5 Specific gravity and Absorption

Table A.26 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/C 20% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2042.92
dry wt.	1967.91
SSD supmerged	1196.76
Bulk specific gravity	2.33
Bulk specific gravity (SSD)	2.41
Apparent Specific gravity	2.55
Absorption	3.81%

Specific gravity & Absorption of fine aggregates	
Can wt.	113.42
dry wt. and can wt.	499.27
dry wt.	385.85
SSD wt.	401.06
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2033.11
Bulk specific gravity	2.50
Bulk specific gravity (SSD)	2.60
Apparent Specific gravity	2.78

a.4.6 Sand equivalent and Absorption

Table A.27 shows results of Sand equivalent for R/C 20% material.

	Sample 1	Sample 2
Sand reading	77.5	70
Clay reading	321.5	317.5
Sand equivalent	24.11%	22.05%
Avarage Sand equivalent		23.08%

a.4.7 Los Angeles test

Table A.28 shows results of Los Angeles test for R/C 20% material.

wt. of sample (g)	5000
wt. of losses (g)	1590
Los Angeles ratio	31.80%

a.5 R/C 30% material:

a.5.1 Gradation

Table A.29 shows results of sieve analysis test of R/C 30% material:

Wt. passing #4 : B	5091.08
Wt. retauned on #4	11145
Wt. mixed sample : A	16236.08
wt. small sample passing #4 befor washing: C	980.55

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	215			16021.08		98.68
37.5	1695			14326.08		88.24
25	2515			11811.08		72.75
19	1395			10416.08		64.15
12.5	2305			8111.08		49.96
9.5	1030			7081.08		43.61
4.75	1990			5091.08		31.36
2		280.48	700.07		71.40	22.39
1.18		136.63	563.44		57.46	18.02
0.6		108.52	454.92		46.39	14.55
0.425		49.01	405.91		41.40	12.98
0.3		43.07	362.84		37.00	11.60
0.15		72.52	290.32		29.61	9.28
0.075		42.62	247.7		25.26	7.92

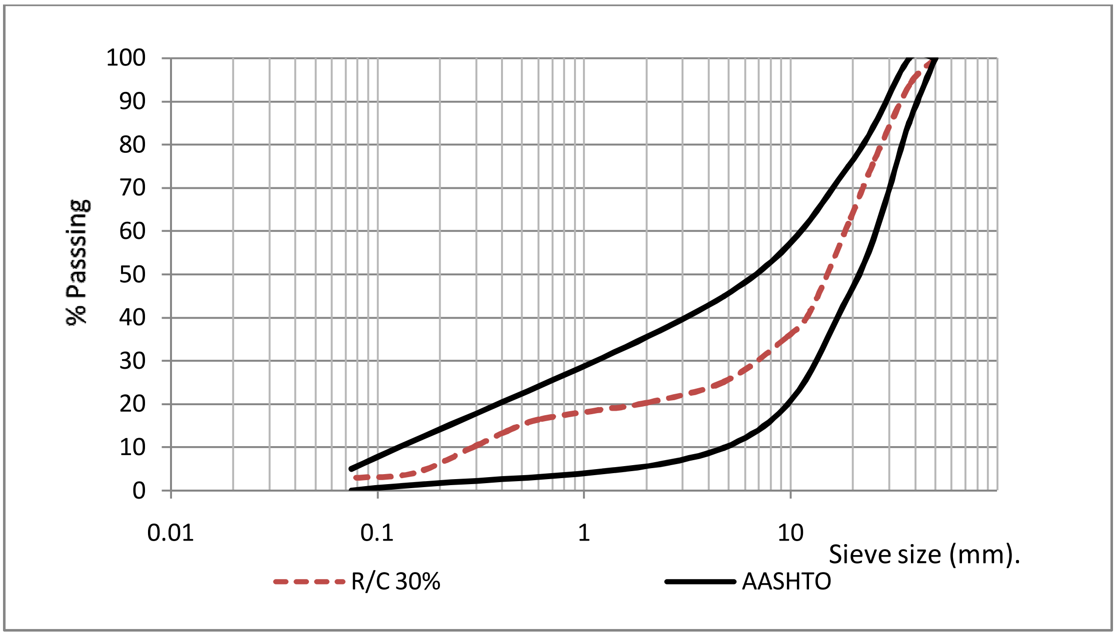

Figure A.17 R/C 30% material gradation.

a.5.2 Atterberg limits

Table A.30 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/C 30% material.

Plastic limit	
Can no	L-12
Wt. of can	36.35
wt. wet soil and can	49.39
wt. dry soil amd can	47.68
water wt.	1.71
dry wt.	11.33
water content	15.09
Plastic limit	16.5%

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
L-16	30.66	72.22	64.93	7.29	34.27	21.27	21.25
L-18	34.44	80.97	72.97	8	38.53	20.76	20.3
At penetration 20mm water content 20.6							
L.L = 20.60%							

Plastic Index	4.10 %

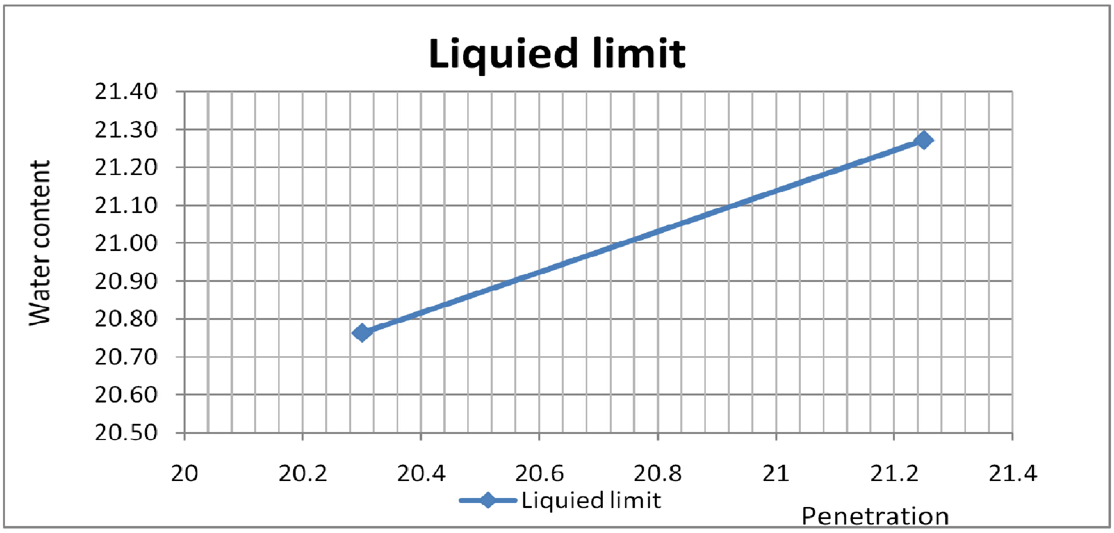

Figure A.18 R/C 30% material Liquid limit

a.5.3 California bearing ratio

Table A.31 shows results of CBR for R/C 30% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.360	80.94	26.98
1	0.039	0.950	213.58	71.19
1.5	0.059	1.990	447.39	149.13
2	0.079	3.240	728.42	242.81
2.5	0.098	4.530	1018.44	339.48
3	0.118	5.930	1333.18	444.40
4	0.157	9.330	2097.57	699.20
5	0.197	13.260	2981.12	993.72
5.597	0.220	15.491	3482.69	1160.92

CBR 0 .1	80
CBR 0.2	104
Take CBR	104%

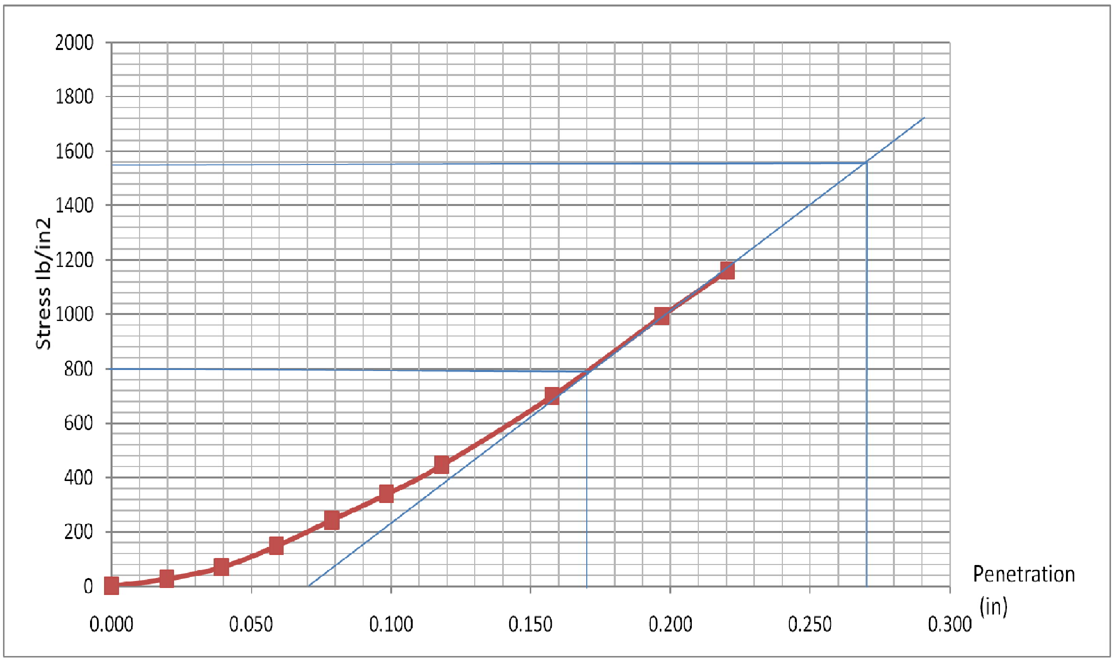

Figure A.19 R/C 30% material CBR

a.5.4 Modified Proctor

Table A.32 shows results of modified proctor compaction test for R/C 30% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
X5	108.77	566.57	550.43	3.65
L12	36.39	386.41	366.29	6.10
L3	58.7	342.78	319.31	9.01
L18	34.45	318.08	289	11.42

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4920	9300	4380	2.06	1.990
4920	9610	4690	2.21	2.081
4920	9815	4895	2.30	2.114
4920	9815	4895	2.30	2.069

mold volume	2123.7635
Pd max	2.116
W	8.8%

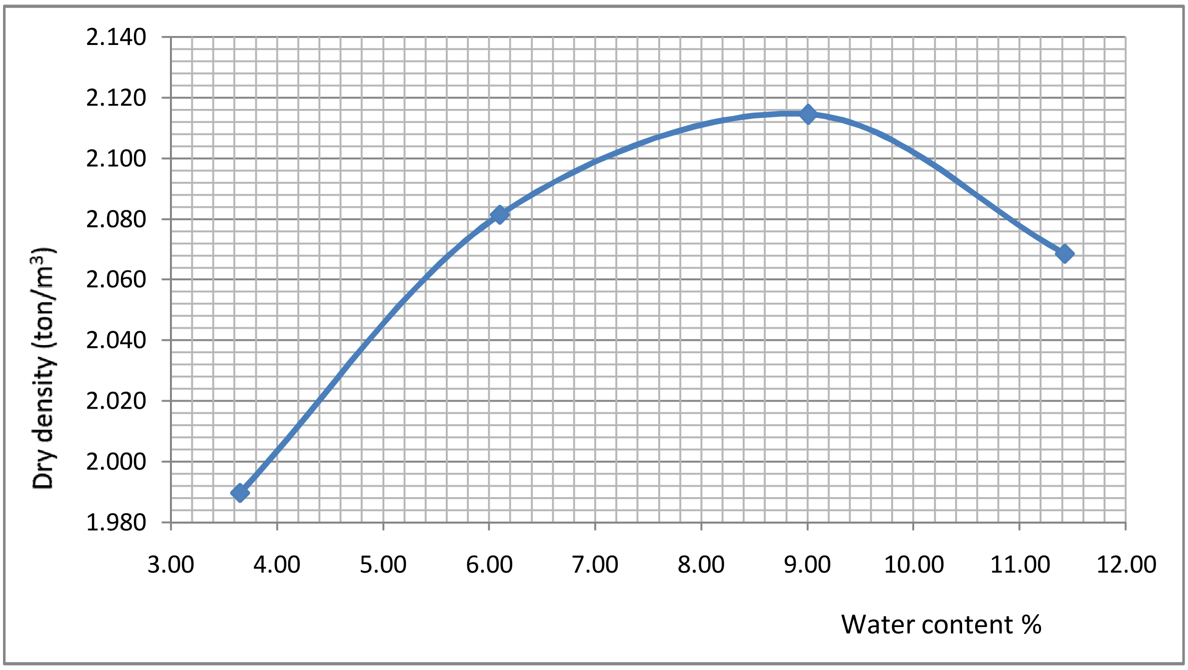

Figure A.20 R/C 30% material Proctor test

a.5.5 Specific gravity and Absorption

Table A.33 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/C 30% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2006.77
dry wt.	1915.93
SSD supmerged	1180.88
Bulk specific gravity	2.32
Bulk specific gravity (SSD)	2.43
Apparent Specific gravity	2.61
Absorption	4.74%

Specific gravity & Absorption of fine aggregates	
Can wt.	97.91
dry wt. and can wt.	491.72
dry wt.	393.81
SSD wt.	402.69
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2035.95
Bulk specific gravity	2.58
Bulk specific gravity (SSD)	2.63
Apparent Specific gravity	2.74

a.5.6 Sand equivalent and Absorption

Table A.34 shows results of Sand equivalent for R/C 30% material.

	Sample 1	Sample 2
Sand reading	72	72.5
Clay reading	320	324
Sand equivalent	22.50%	22.38%
Avarage Sand equivalent		22.44%

a.5.7 Los Angeles test

Table A.35 shows results of Los Angeles test for R/C 30% material.

wt. of sample (g)	5000
wt. of losses (g)	1610
Los Angeles ratio	32.20%

a.6 R/C 40% material:

a.6.1 Gradation

Table A.36 shows results of sieve analysis test of R/C 40% material:

Wt. passing #4 : B	4579.34
Wt. retauned on #4	12990
Wt. mixed sample : A	17569.34
wt. small sample passing #4 befor washing: C	962.68

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	1170			16399.34		93.34
37.5	2165			14234.34		81.02
25	2665			11569.34		65.85
19	1425			10144.34		57.74
12.5	2260			7884.34		44.88
9.5	1330			6554.34		37.31
4.75	1975			4579.34		26.06
2		271.67	691.01		71.78	18.71
1.18		128.89	562.12		58.39	15.22
0.6		110.21	451.91		46.94	12.24
0.425		53.86	398.05		41.35	10.78
0.3		60.35	337.7		35.08	9.14
0.15		92.81	244.89		25.44	6.63
0.075		37.49	207.4		21.54	5.62

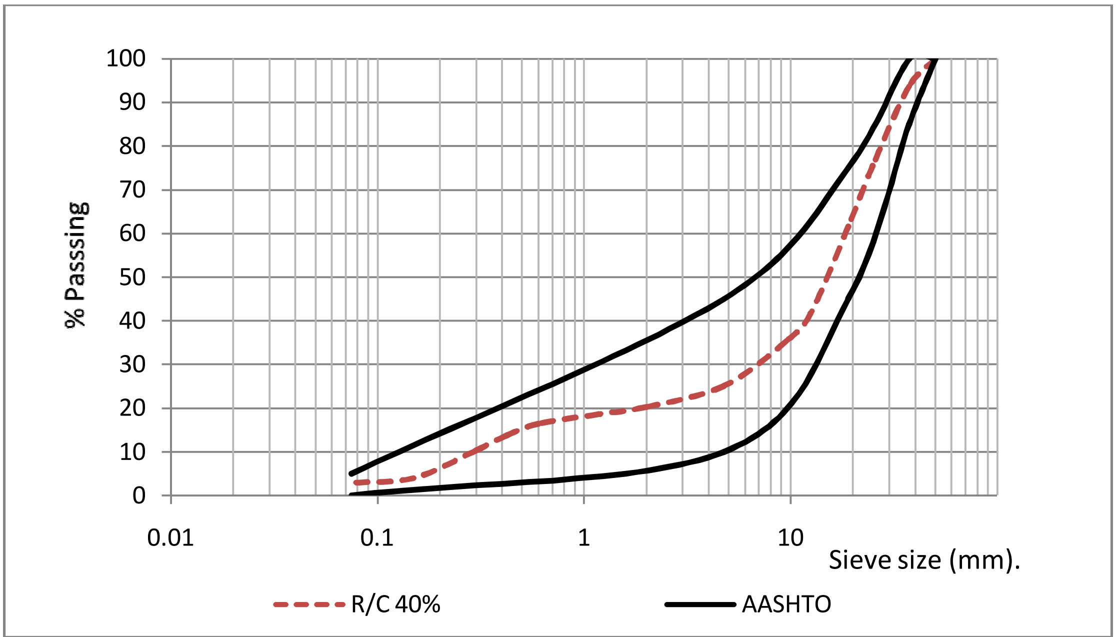

Figure A.21 R/C 40% material gradation.

a.6.2 Atterberg limits

Table A.37 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/C 40% material.

Plastic limit	
Can no	C-3
Wt. of can	47.66
wt. wet soil and can	54.96
wt. dry soil amd can	53.88
water wt.	1.08
dry wt.	6.22
water content	17.36
Plastic limit	17.4%

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C-5	48.18	73	69.08	3.92	20.9	18.76	17.7
E-1	47.04	81.12	75.44	5.68	28.4	20.00	20.85
At penetration 20mm water content 19.63							
L.L = 19.60%							

Plastic Index	2.20 %

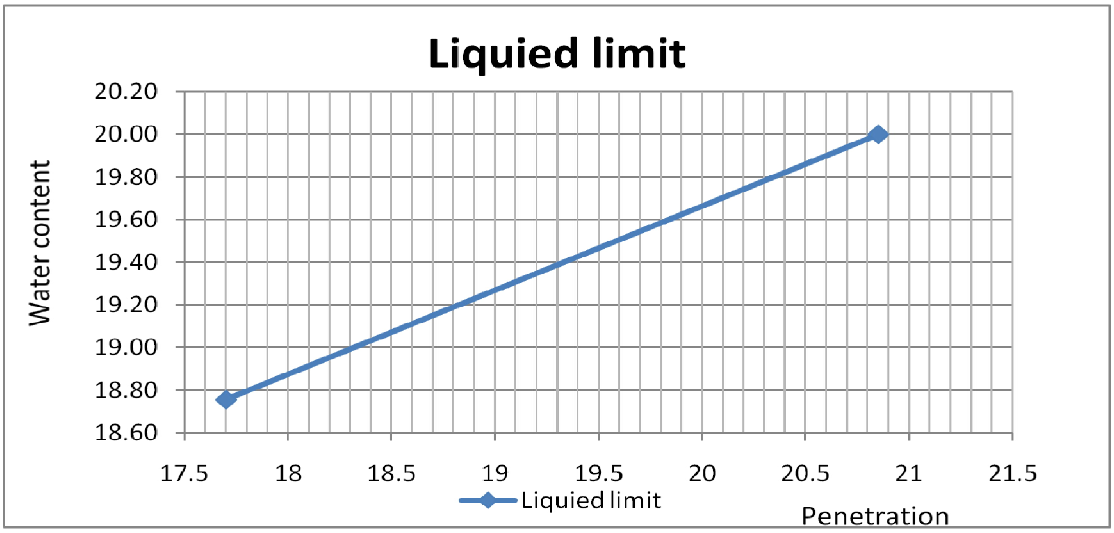

Figure A.22 R/C 40% material Liquid limit

a.6.3 California bearing ratio

Table A.38 shows results of CBR for R/C 40% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.615	138.26	46.09
1	0.039	1.400	314.75	104.92
1.5	0.059	2.590	582.28	194.10
2	0.079	3.990	897.03	299.02
2.5	0.098	5.590	1256.74	418.92
3	0.118	7.280	1636.69	545.57
4	0.157	11.000	2473.02	824.35
5	0.197	15.320	3444.24	1148.10
5.282	0.208	16.364	3678.96	1226.34

CBR 0 .1	7
CBR 0.2	104.00
Take CBR	104%

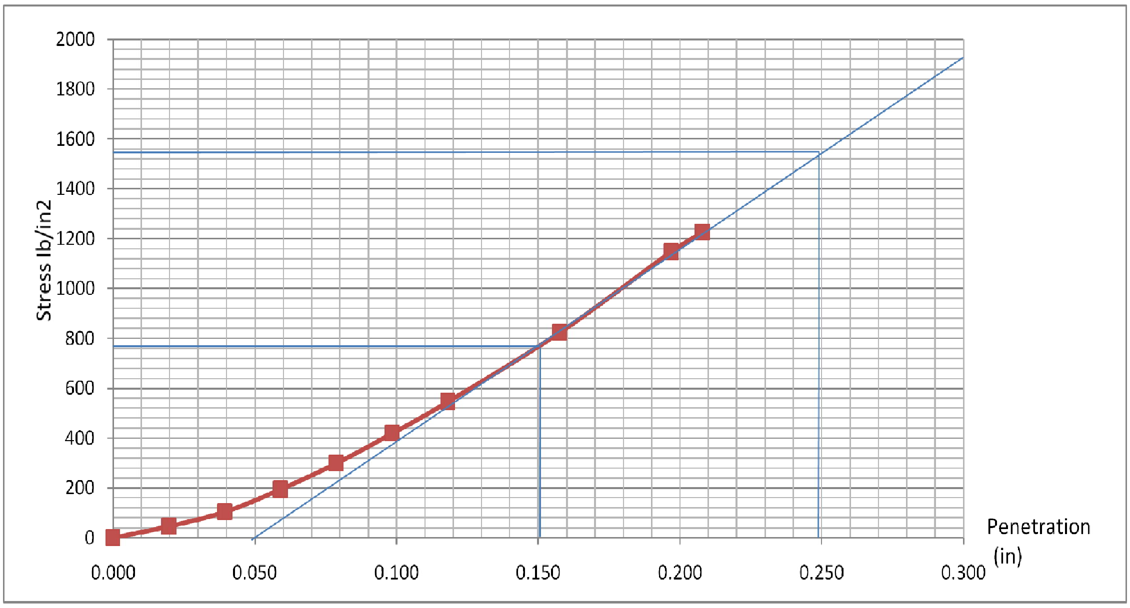

Figure A.23 R/C 40% material CBR

a.6.4 Modified Proctor

Table A.39 shows results of modified proctor compaction test for R/C 40% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
N16	105.52	532.12	515.3	4.10
L10	32.66	453.02	427.72	6.40
L18	34.43	500.42	461.35	9.15
L11	32.62	467.76	425.29	10.82

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4920	9305	4385	2.06	1.983
4920	9635	4715	2.22	2.086
4920	9800	4880	2.30	2.105
4920	9720	4800	2.26	2.040

mold volume	2123.7635
Pd max	2.108
W	8.4%

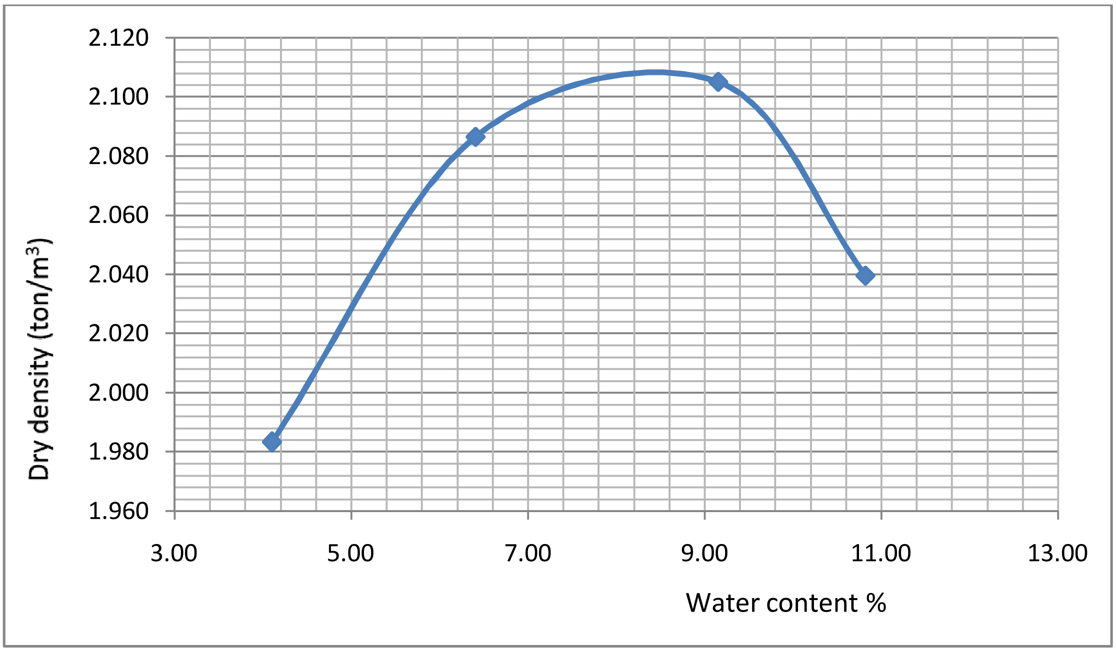

Figure A.24 R/C 40% material Proctor test

a.6.5 Specific gravity and Absorption

Table A.40 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/C 40% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2042.85
dry wt.	1968.98
SSD supmerged	1194.56
Bulk specific gravity	2.32
Bulk specific gravity (SSD)	2.41
Apparent Specific gravity	2.54
Absorption	3.75%

Specific gravity & Absorption of fine aggregates	
Can wt.	95.79
dry wt. and can wt.	373.94
dry wt.	278.15
SSD wt.	288.14
Bicnometer filled with water	1782.38
Bicnometer filled with SSD sample & water	1958.9
Bulk specific gravity	2.49
Bulk specific gravity (SSD)	2.58
Apparent Specific gravity	2.74

a.6.6 Sand equivalent and Absorption

Table A.41 shows results of Sand equivalent for R/C 40% material.

	Sample 1	Sample 2
Sand reading	70	71
Clay reading	266	288.5
Sand equivalent	26.32%	24.61%
Avarage Sand equivalent		25.46%

a.6.7 Los Angeles test

Table A.42 shows results of Los Angeles test for R/C 40% material.

wt. of sample (g)	5000
wt. of losses (g)	1615
Los Angeles ratio	32.30%

a.7 R/C 50% material:

a.7.1 Gradation

Table A.43 shows results of sieve analysis test of R/C 50% material:

Wt. passing #4 : B	3364.06
Wt. retauned on #4	12845
Wt. mixed sample : A	16209.06
wt. small sample passing #4 befor washing: C	982.36

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Rate passing less then #4 from smale sample	Finall rate Passing
50	1085			15124.06		93.31
37.5	2195			12929.06		79.76
25	2825			10104.06		62.34
19	1525			8579.06		52.93
12.5	2505			6074.06		37.47
9.5	1090			4984.06		30.75
4.75	1620			3364.06		20.75
2		293	689.36		70.17	14.56
1.18		141	548.36		55.82	11.59
0.6		106.6	441.76		44.97	9.33
0.425		50.09	391.67		39.87	8.27
0.3		46.53	345.14		35.13	7.29
0.15		76.22	268.92		27.37	5.68
0.075		38.62	230.3		23.44	4.87

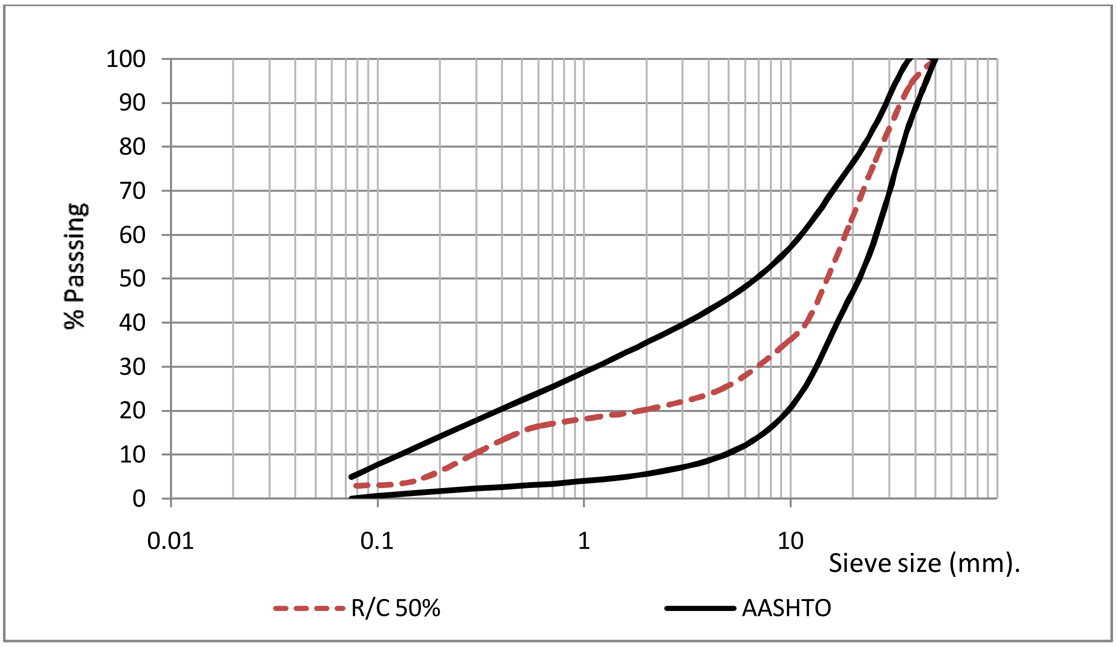

Figure A.25 R/C 50% material gradation.

a.7.2 Atterberg limits

Table A.44 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/C 50% material.

Plastic limit	
Can no	C-29
Wt. of can	24.5
wt. wet soil and can	34.25
wt. dry soil amd can	32.9
water wt.	1.35
dry wt.	8.4
water content	16.07
Plastic limit	16.0%

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C-6	49.17	76.8	72.14	4.66	22.97	20.29	20.9
C-11	25.11	55.48	50.47	5.01	25.36	19.76	18.1
At penetration 20mm water content 20.1							
L.L = 20.10%							

Plastic Index	4.10 %

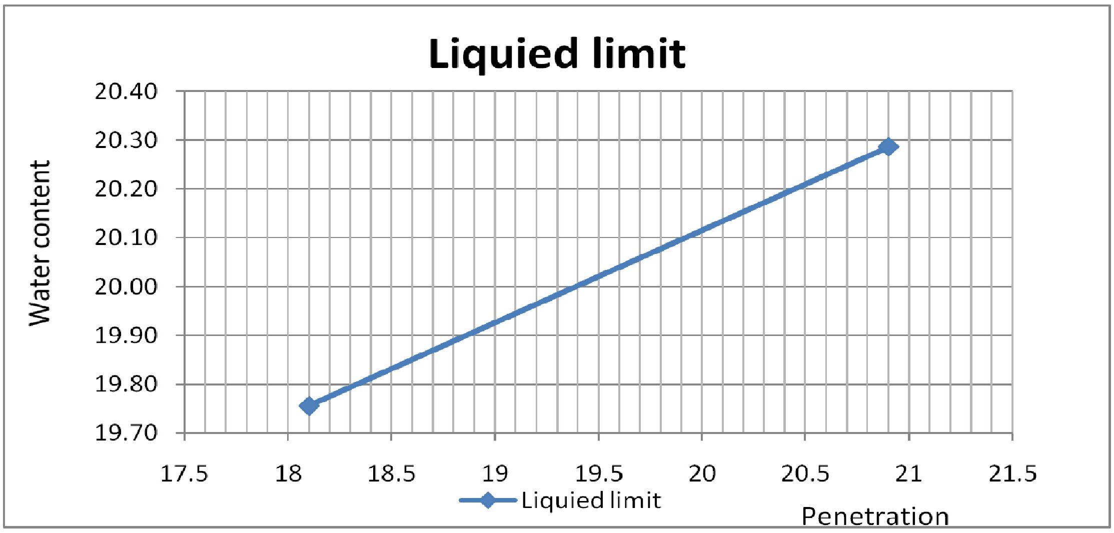

Figure A.26 R/C 50% material Liquid limit

a.7.3 California bearing ratio

Table A.45 shows results of CBR for R/C 50% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.580	130.40	43.47
1	0.039	1.390	312.50	104.17
1.5	0.059	2.630	591.28	197.10
2	0.079	3.990	897.03	299.02
2.5	0.098	5.540	1245.50	415.18
3	0.118	7.150	1607.46	535.83
4	0.157	10.480	2356.12	785.39
5	0.197	14.240	3201.44	1067.16

CBR 0 .1	70
CBR 0.2	93.00
Take CBR	93%

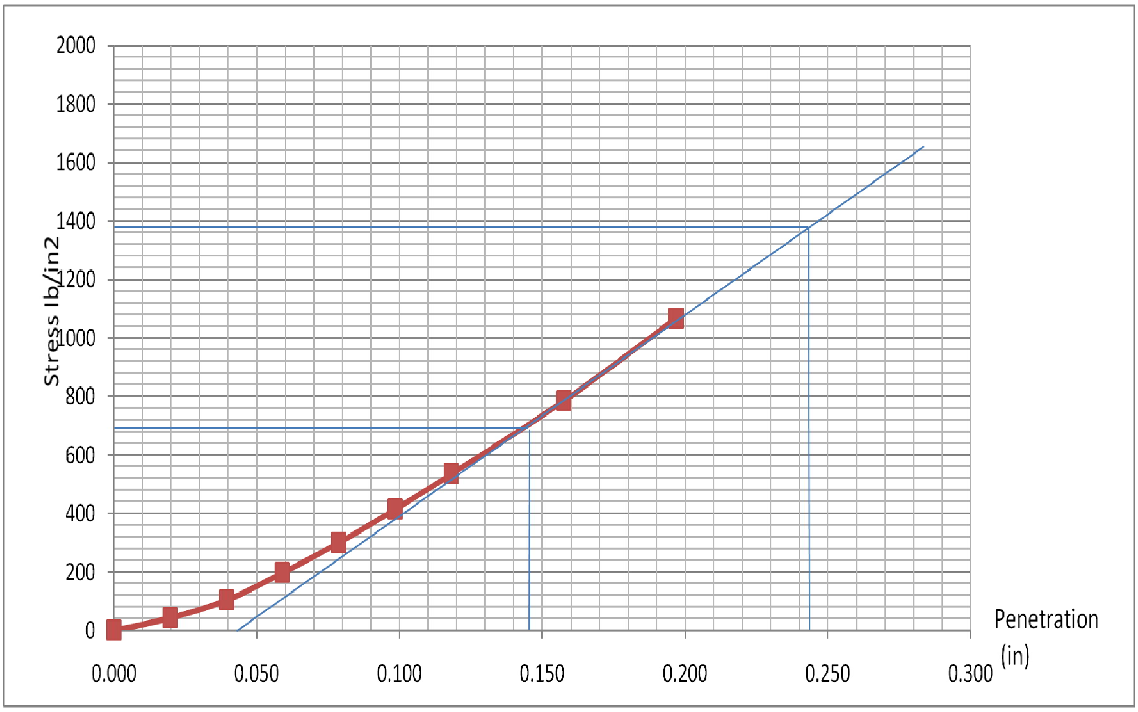

Figure A.27 R/C 50% material CBR

a.7.4 Modified Proctor

Table A.46 shows results of modified proctor compaction test for R/C 50% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
F8	90.12	481.45	467.74	3.63
X101	97.66	541.03	514.98	6.24
L9	32.74	535.37	494.15	8.93
Q11	113.3	688.85	625.48	12.37

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4920	9195	4275	2.01	1.942
4920	9580	4660	2.19	2.065
4920	9760	4840	2.28	2.092
4920	9685	4765	2.24	1.997

mold volume	2123.7635
Pd max	2.096
W	8.2%

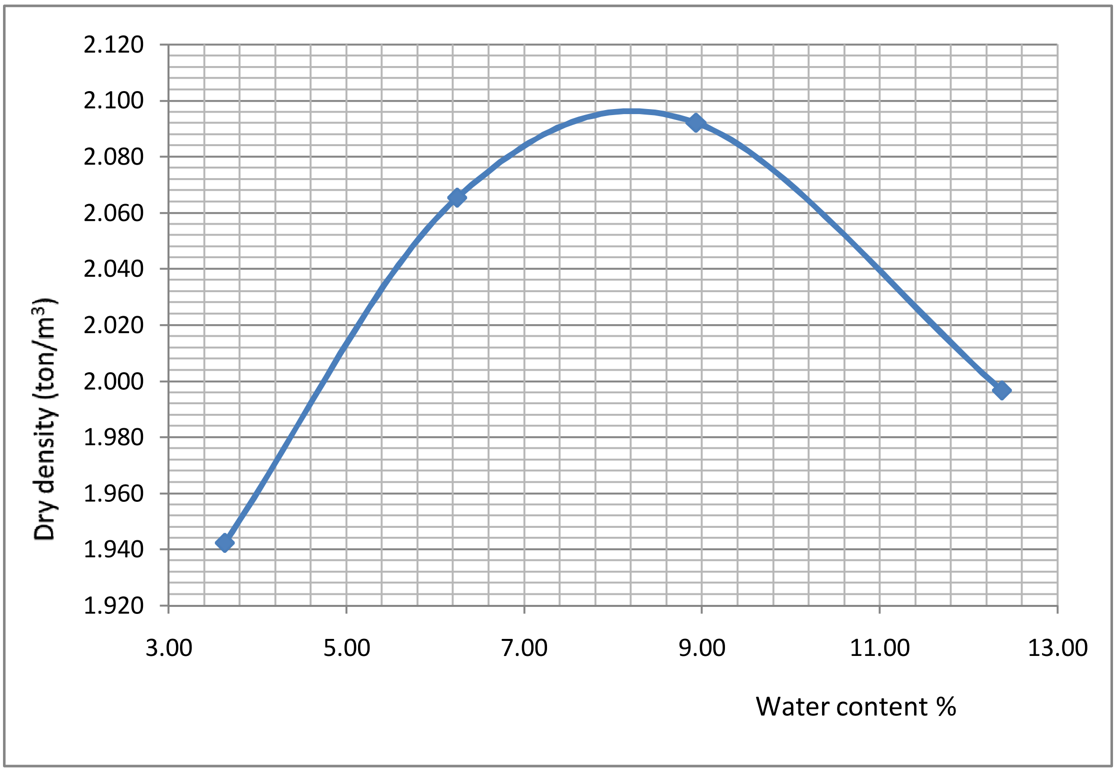

Figure A.28 R/C 50% material Proctor test

a.7.5 Specific gravity and Absorption

Table A.47 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/C 50% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	1984.15
dry wt.	1906.27
SSD supmerged	1173.65
Bulk specific gravity	2.35
Bulk specific gravity (SSD)	2.45
Apparent Specific gravity	2.60
Absorption	4.09%

Specific gravity & Absorption of fine aggregates	
Can wt.	114.23
dry wt. and can wt.	511.03
dry wt.	396.8
SSD wt.	407.32
Bicnometer filled with water	1782.38
Bicnometer filled with SSD sample & water	2035.05
Bulk specific gravity	2.57
Bulk specific gravity (SSD)	2.63
Apparent Specific gravity	2.75

a.7.6 Sand equivalent and Absorption

Table A.48 shows results of Sand equivalent for R/C 50% material.

	Sample 1	Sample 2
Sand reading	82.5	77.5
Clay reading	302	304
Sand equivalent	27.32%	25.49%
Avarage Sand equivalent		26.41%

a.7.7 Los Angeles test

Table A.49 shows results of Los Angeles test for R/C 50% material.

wt. of sample (g)	5000
wt. of losses (g)	1465
Los Angeles ratio	29.30%

a.8 R/D 10% material:

a.8.1 Gradation

Table A.50 shows results of sieve analysis test of R/D 10% material:

Wt. passing #4 : B	1484.5
Wt. retauned on #4	8064
Wt. mixed sample : A	9548.5

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Finall rate Passing
50	415			9133.5	95.65
37.5	490			8643.5	90.52
25	2040			6603.5	69.16
19	1015			5588.5	58.53
12.5	2260			3328.5	34.86
9.5	800			2528.5	26.48
4.75	980			1548.5	16.22
2		297.5	1251		13.10
1.18		112.31	1138.69		11.93
0.6		162.47	976.22		10.22
0.425		173.8	802.42		8.40
0.3		188.45	613.97		6.43
0.15		315.1	298.87		3.13
0.075		59.77	239.1		2.50

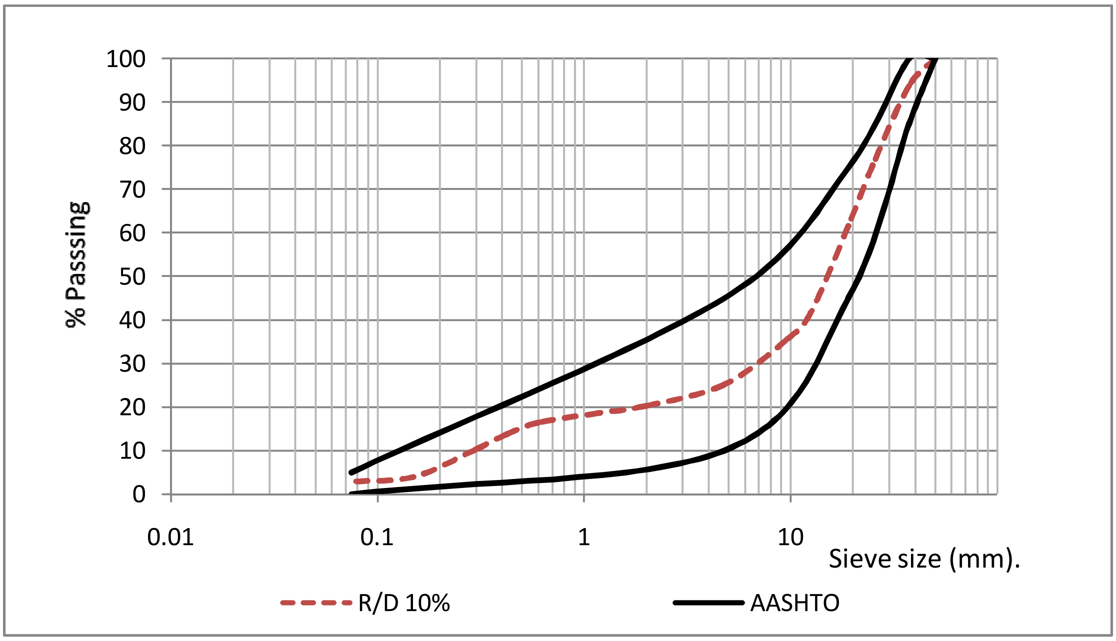

Figure A.29 R/D 10% material gradation.

a.8.2 Atterberg limits

Table A.51 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/D 10% material.

Plastic limit	
Plastic limit	Non-Plastic

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C26	25.81	56.15	50.78	5.37	24.97	21.51	17.6
C30	28.5	70.94	63.23	7.71	34.73	22.20	18.9
C22	22.04	58.79	51.75	7.04	29.71	23.70	22
At penetration 20mm water content 22.75							
L.L = 22.75%							

Plastic Index	-

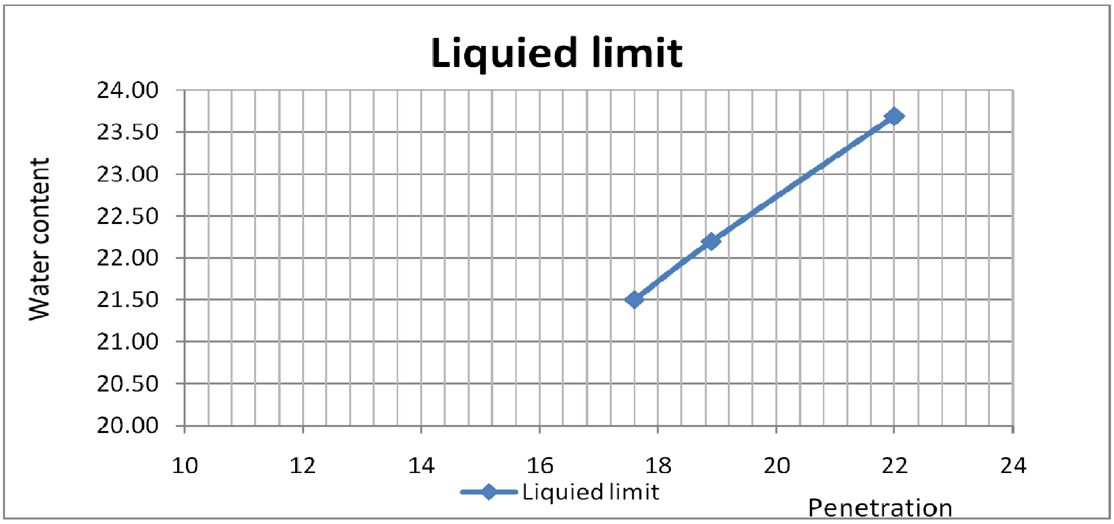

Figure A.30 R/D 10% material Liquid limit

a.8.3 California bearing ratio

Table A.52 shows results of CBR for R/D 10% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.710	159.62	53.21
1	0.039	1.670	375.45	125.15
1.5	0.059	3.090	694.69	231.57
2	0.079	4.850	1090.38	363.47
2.5	0.098	6.880	1546.76	515.60
3	0.118	8.870	1994.15	664.73
4	0.157	13.540	3044.06	1014.71
4.381	0.172	15.349	3450.76	1150.27

CBR 0 .1	87
CBR 0.2	117.33
Take CBR	117%

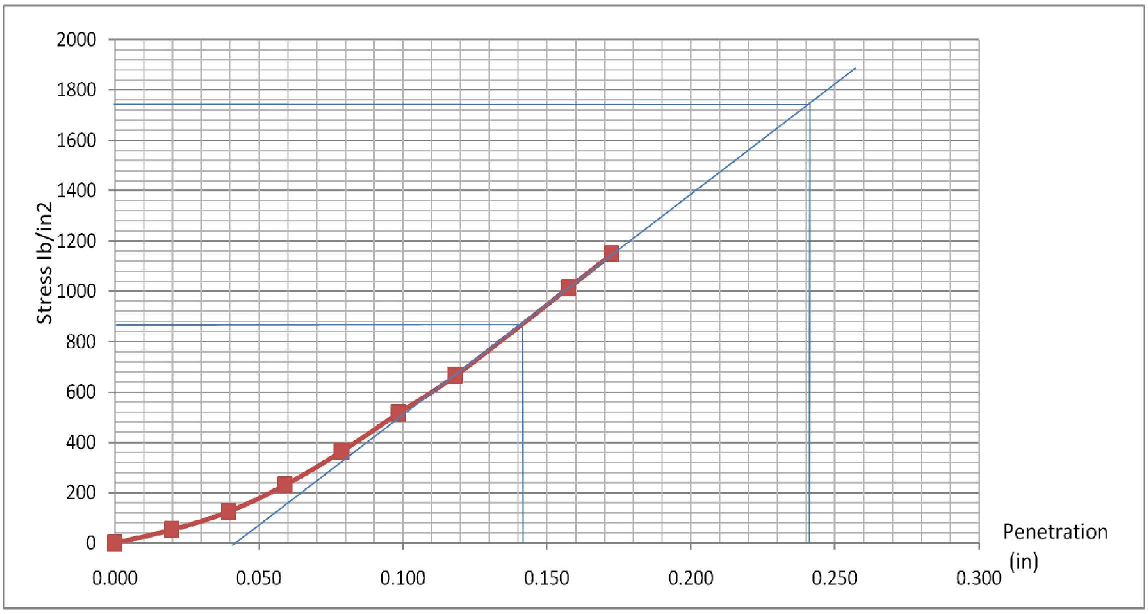

Figure A.31 R/D 10% material CBR

a.8.4 Modified Proctor

Table A.53 shows results of modified proctor compaction test for R/D 10% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
L12	36.44	397.72	380.28	5.07
L11	32.65	398.47	375.67	6.65
L10	32.65	427.63	397.97	8.12
L18	34.45	318.08	290.41	10.81
L19	32.69	604.51	539.57	12.81

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4925	8950	4025	1.90	1.804
4925	9185	4260	2.01	1.881
4925	9345	4420	2.08	1.925
4925	9630	4705	2.22	1.999
4925	9660	4735	2.23	1.976

mold volume	2123.7635
Pd max	2.00
W	11.2%

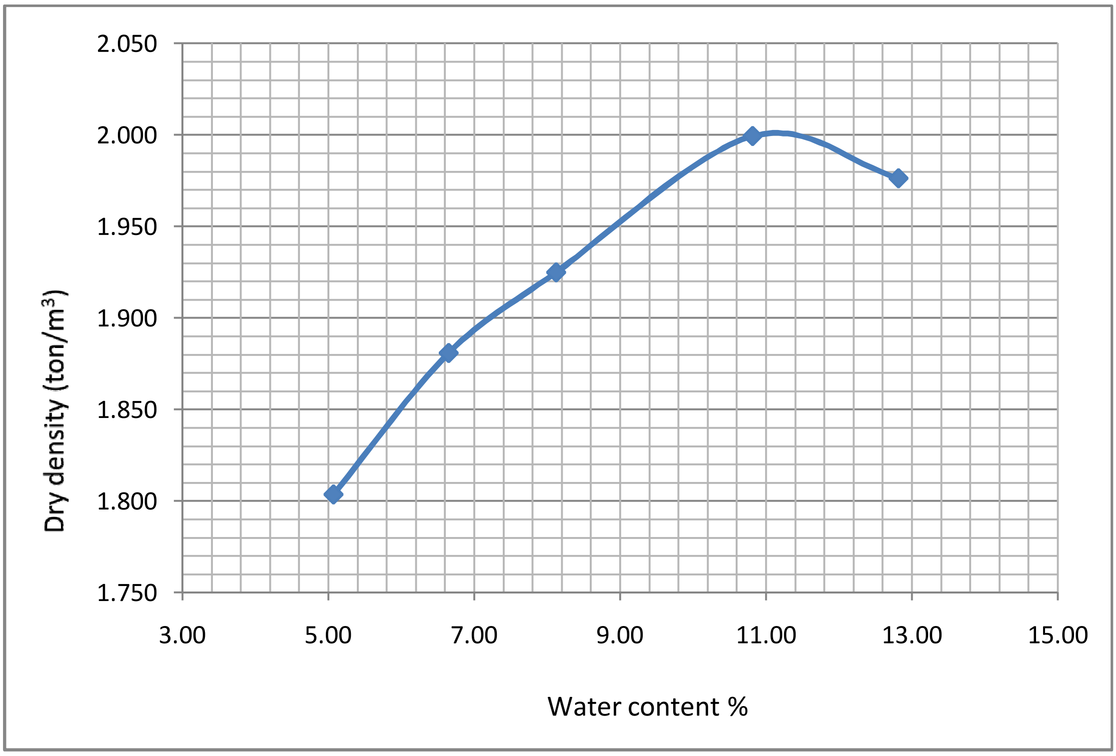

Figure A.32 R/D 10% material Proctor test

a.8.5 Specific gravity and Absorption

Table A.54 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/D 10% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2027.69
dry wt.	1933.3
SSD supmerged	1174.09
Bulk specific gravity	2.26
Bulk specific gravity (SSD)	2.38
Apparent Specific gravity	2.55
Absorption	4.88%

Specific gravity & Absorption of fine aggregates	
Can wt.	113.27
dry wt. and can wt.	484.5
dry wt.	371.23
SSD wt.	388.21
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2016.46
Bulk specific gravity	2.35
Bulk specific gravity (SSD)	2.46
Apparent Specific gravity	2.64

a.8.6 Sand equivalent and Absorption

Table A.55 shows results of Sand equivalent for R/D 10% material.

	Sample 1	Sample 2
Sand reading	110	112
Clay reading	167.5	170
Sand equivalent	65.67%	65.88%
Avarage Sand equivalent		65.78%

a.8.7 Los Angeles test

Table A.56 shows results of Los Angeles test for R/D 10% material.

wt. of sample (g)	5000
wt. of losses (g)	2178.5
Los Angeles ratio	43.57%

a.9 R/D 20% material:

a.9.1 Gradation

Table A.57 shows results of sieve analysis test of R/D 20% material:

Wt. passing #4 : B	1407
Wt. retauned on #4	8884
Wt. mixed sample : A	10291

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Finall rate Passing
50	400			9891	96.11
37.5	635			9256	89.94
25	2010			7246	70.41
19	1360			5886	57.20
12.5	2410			3476	33.78
9.5	910			2566	24.93
4.75	1070			1496	14.54
2		350.7	1145.3		11.13
1.18		119.1	1026.2		9.97
0.6		150	876.2		8.51
0.425		148.23	727.97		7.07
0.3		171	556.97		5.41
0.15		272	284.97		2.77
0.075		55.4	229.57		2.23

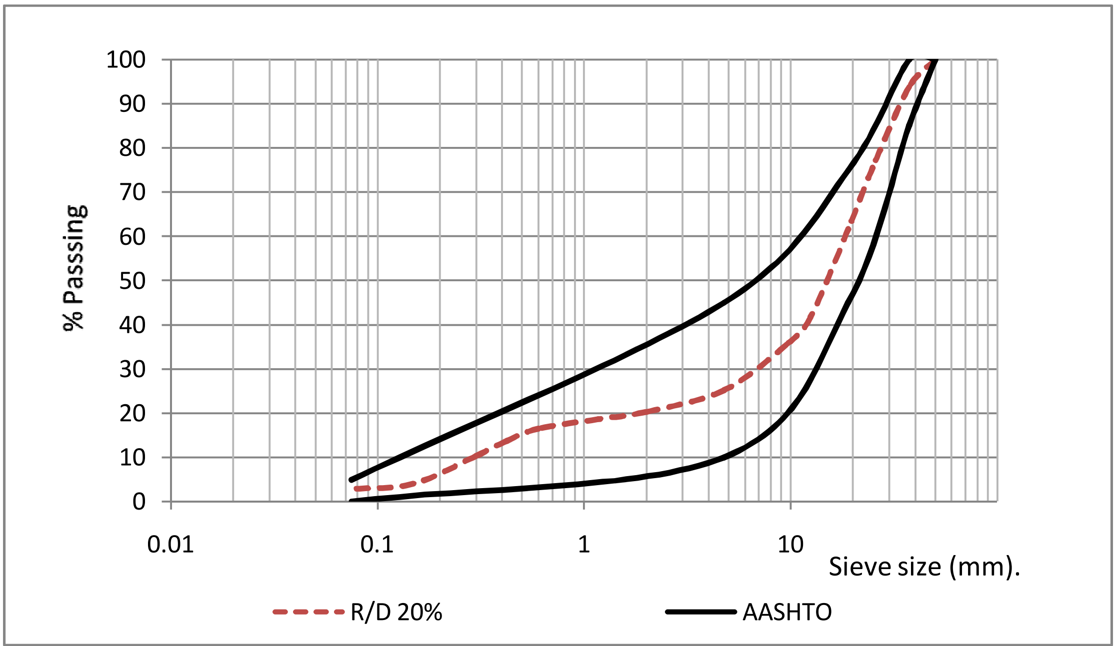

Figure A.33 R/D 20% material gradation.

a.9.2 Atterberg limits

Table A.58 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/D 20% material.

Plastic limit	
Plastic limit	Non-Plastic

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C7	47.96	114.87	102.41	12.46	54.45	22.88	20.7
At penetration 20mm water content 22.88							
L.L = 22.88%							

Plastic Index	-

a.9.3 California bearing ratio

Table A.59 shows results of CBR for R/D 20% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.452	101.62	33.87
1	0.039	1.050	236.06	78.69
1.5	0.059	1.912	429.86	143.29
2	0.079	2.990	672.21	224.07
2.5	0.098	4.230	950.99	317.00
3	0.118	5.915	1329.81	443.28
4	0.157	9.580	2153.78	717.94
5	0.197	13.730	3086.78	1028.94
5.351	0.211	15.063	3386.47	1128.84

CBR 0 .1	80
CBR 0.2	106.7
Take CBR	107 %

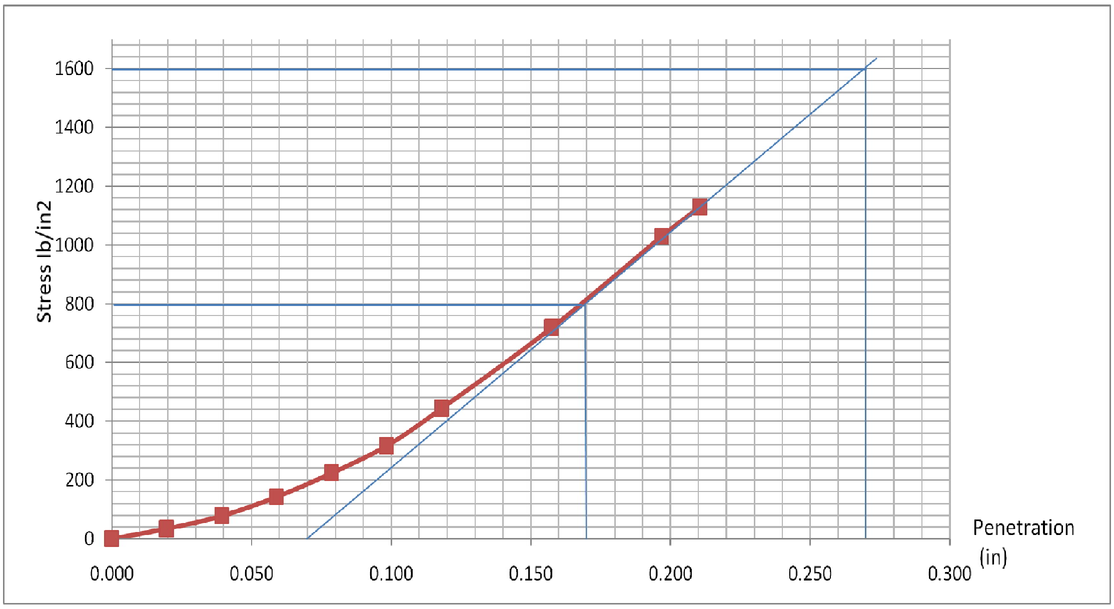

Figure A.34 R/D 20% material CBR

a.9.4 Modified Proctor

Table A.60 shows results of modified proctor compaction test for R/D 20% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
N4	116.12	449.57	431.95	5.58
L9	32.73	488.89	453.99	8.28
L16	30.7	444.5	402.17	11.40
L3	58.71	480.03	430.14	13.43
P1	98.43	930.88	816.67	15.90

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4925	9080	4155	1.96	1.853
4925	9235	4310	2.03	1.874
4925	9565	4640	2.18	1.961
4925	9685	4760	2.24	1.976
4925	9720	4795	2.26	1.948

mold volume	2123.7635
Pd max	1.98
W	13%

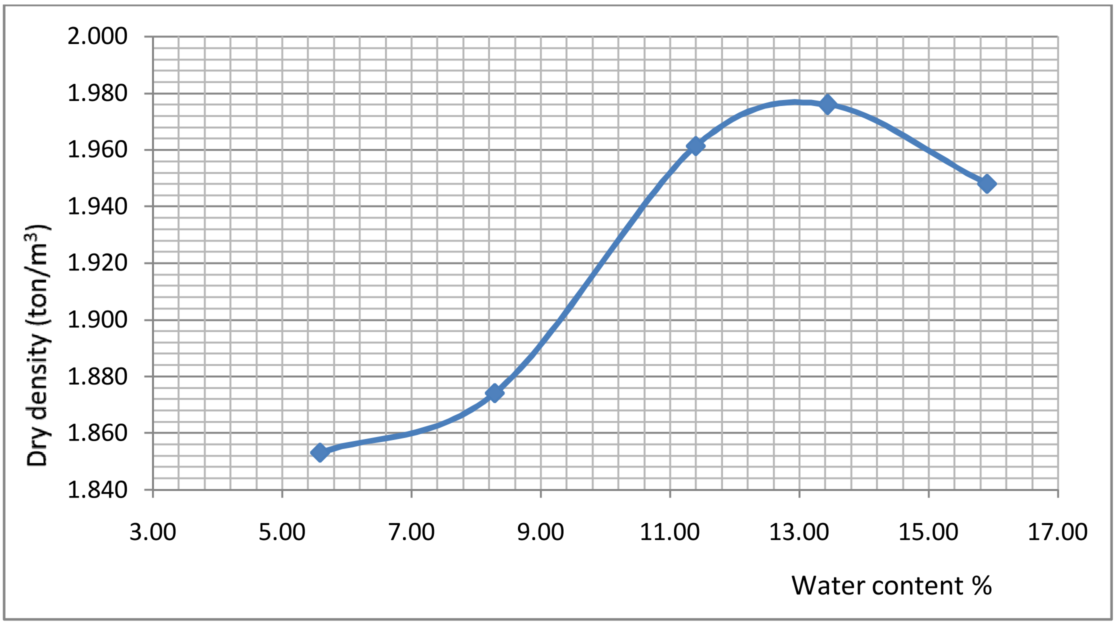

Figure A.35 R/D 20% material Proctor test

a.9.5 Specific gravity and Absorption

Table A.61 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/D 20% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	1935.01
dry wt.	1831.46
SSD supmerged	1112.63
Bulk specific gravity	2.23
Bulk specific gravity (SSD)	2.35
Apparent Specific gravity	2.55
Absorption	5.65%

Specific gravity & Absorption of fine aggregates	
Can wt.	525.45
dry wt. and can wt.	918.2
dry wt.	392.75
SSD wt.	416.41
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2030.21
Bulk specific gravity	2.28
Bulk specific gravity (SSD)	2.42
Apparent Specific gravity	2.64

a.9.6 Sand equivalent and Absorption

Table A.62 shows results of Sand equivalent for R/D 20% material.

	Sample 1	Sample 2
Sand reading	90	97
Clay reading	142	125
Sand equivalent	63.38%	77.60%
Avarage Sand equivalent		70.49%

a.9.7 Los Angeles test

Table A.63 shows results of Los Angeles test for R/D 20% material.

wt. of sample (g)	5000
wt. of losses (g)	2012.2
Los Angeles ratio	40.24%

a.10 R/D 30% material:

a.10.1 Gradation

Table A.64 shows results of sieve analysis test of R/D 30% material:

Wt. passing #4 : B	1290
Wt. retauned on #4	6900
Wt. mixed sample : A	8190

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Finall rate Passing
50	0			8190	100.00
37.5	990			7200	87.91
25	1360			5840	71.31
19	1000			4840	59.10
12.5	1910			2930	35.78
9.5	685			2245	27.41
4.75	955			1290	15.75
2		315	975		11.90
1.18		105	870		10.62
0.6		120	750		9.16
0.425		120	630		7.69
0.3		160	470		5.74
0.15		260	210		2.56
0.075		40	170		2.08

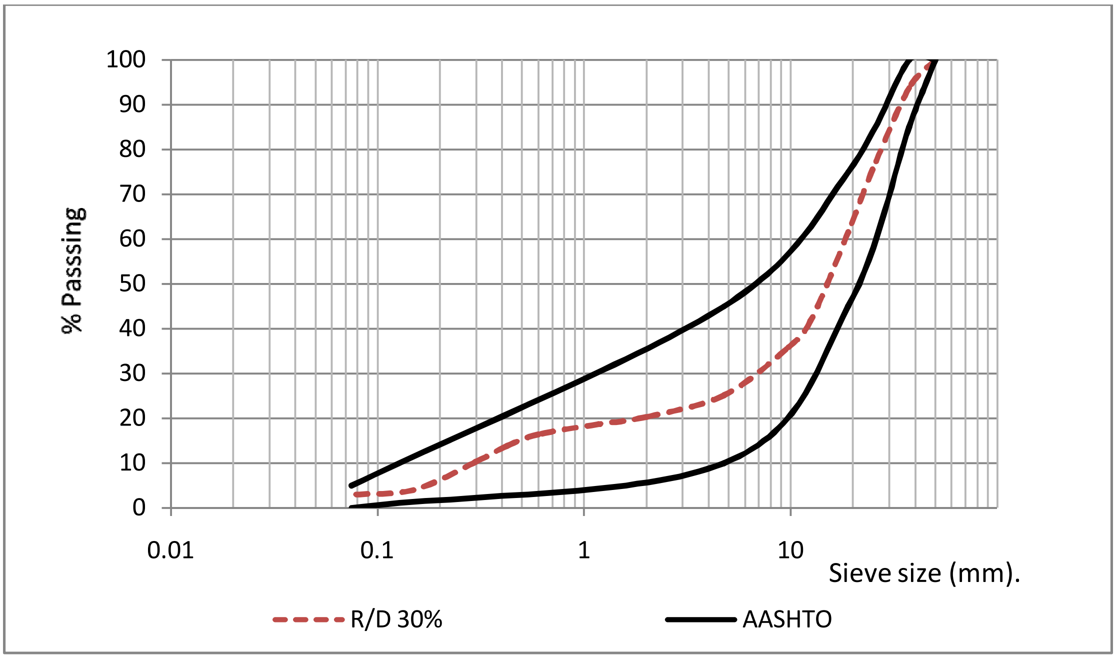

Figure A.36 R/D 30% material gradation.

a.10.2 Atterberg limits

Table A.65 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/D 30% material.

Plastic limit	
Plastic limit	Non-Plastic

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C6	49.23	102.28	92.39	9.89	43.16	22.91	21.5
C28	26.05	91.27	79.74	11.53	53.69	21.48	19.6
At penetration 20mm water content 21.70							
L.L = 21.70%							

Plastic Index	-

a.10.3 California bearing ratio

Table A.66 shows results of CBR for R/D 30% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0.000	0	0
0.5	0.020	0.710	159.62	53.21
1	0.039	1.550	348.47	116.16
1.5	0.059	2.650	595.77	198.59
2	0.079	3.920	881.29	293.77
2.5	0.098	5.400	1214.03	404.68
3	0.118	7.330	1647.93	549.32
4	0.157	12.130	2727.07	909.04
4.611	0.182	15.496	3483.81	1161.29

CBR 0 .1	93
CBR 0.2	125.3
Take CBR	125 %

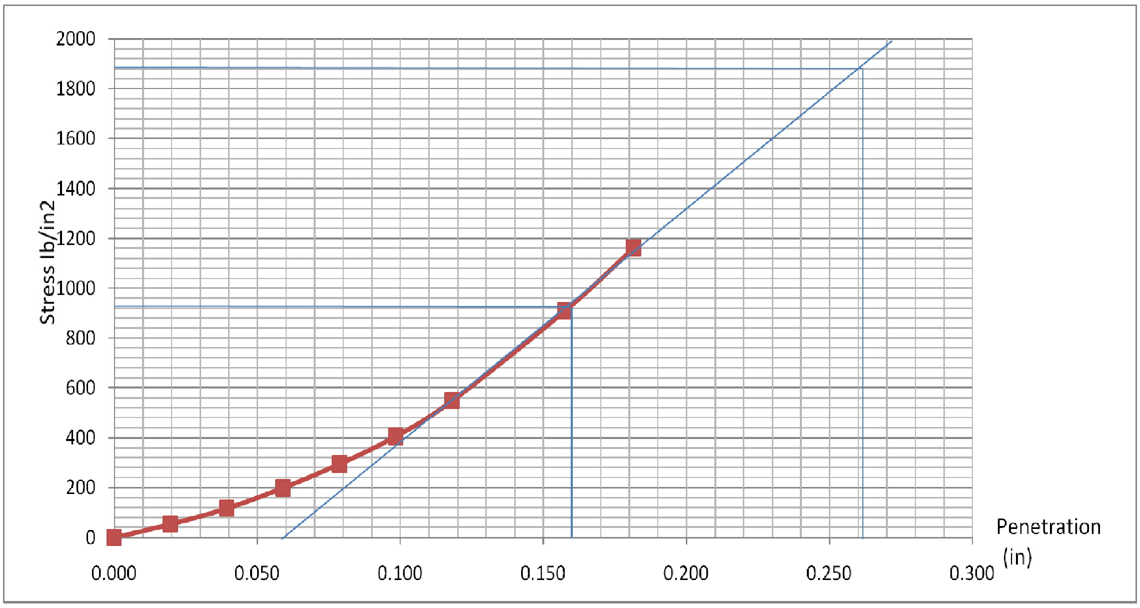

Figure A.37 R/D 30% material CBR

a.10.4 Modified Proctor

Table A.67 shows results of modified proctor compaction test for R/D 30% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
L11	32.6	370.22	349.57	6.51
L12	36.41	435.39	403.22	8.77
L10	32.64	515.32	462.04	12.41
L16	30.68	596.93	524.5	14.67

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4915	9060	4145	1.95	1.832
4915	9305	4390	2.07	1.900
4915	9670	4755	2.24	1.992
4915	9720	4805	2.26	1.973

mold volume	2123.7635
Pd max	1.995
W	13%

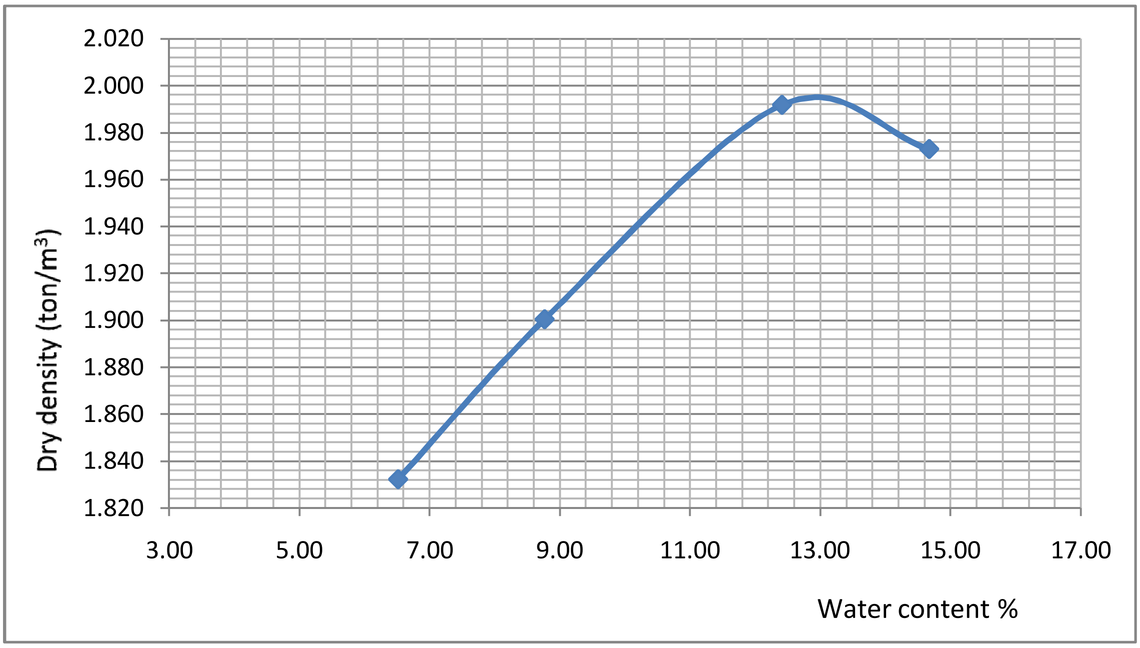

Figure A.38 R/D 30% material Proctor test

a.10.5 Specific gravity and Absorption

Table A.68 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/D 30% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	1985.8
dry wt.	1891.62
SSD supmerged	1137.78
Bulk specific gravity	2.23
Bulk specific gravity (SSD)	2.34
Apparent Specific gravity	2.51
Absorption	4.98%

Specific gravity & Absorption of fine aggregates	
Can wt.	98.39
dry wt. and can wt.	450.27
dry wt.	351.88
SSD wt.	366.47
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2003.58
Bulk specific gravity	2.36
Bulk specific gravity (SSD)	2.46
Apparent Specific gravity	2.62

a.10.6 Sand equivalent and Absorption

Table A.69 shows results of Sand equivalent for R/D 30% material.

	Sample 1	Sample 2
Sand reading	104	105.5
Clay reading	152.5	162.5
Sand equivalent	68.20%	64.92%
Avarage Sand equivalent		66.56 %

a.10.7 Los Angeles test

Table A.70 shows results of Los Angeles test for R/D 30% material.

wt. of sample (g)	5000
wt. of losses (g)	1950
Los Angeles ratio	39.00%

a.11 R/D 40% material:

a.11.1 Gradation

Table A.71 shows results of sieve analysis test of R/D 40% material:

Wt. passing #4 : B	1360
Wt. retauned on #4	7935
Wt. mixed sample : A	9295

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Finall rate Passing
50	170			9125	98.17
37.5	900			8225	88.49
25	1640			6585	70.84
19	925			5660	60.89
12.5	2325			3335	35.88
9.5	800			2535	27.27
4.75	1175			1360	14.63
2		395	965		10.38
1.18		115	850		9.14
0.6		115	735		7.91
0.425		105	630		6.78
0.3		160	470		5.06
0.15		235	235		2.53
0.075		45	190		2.04

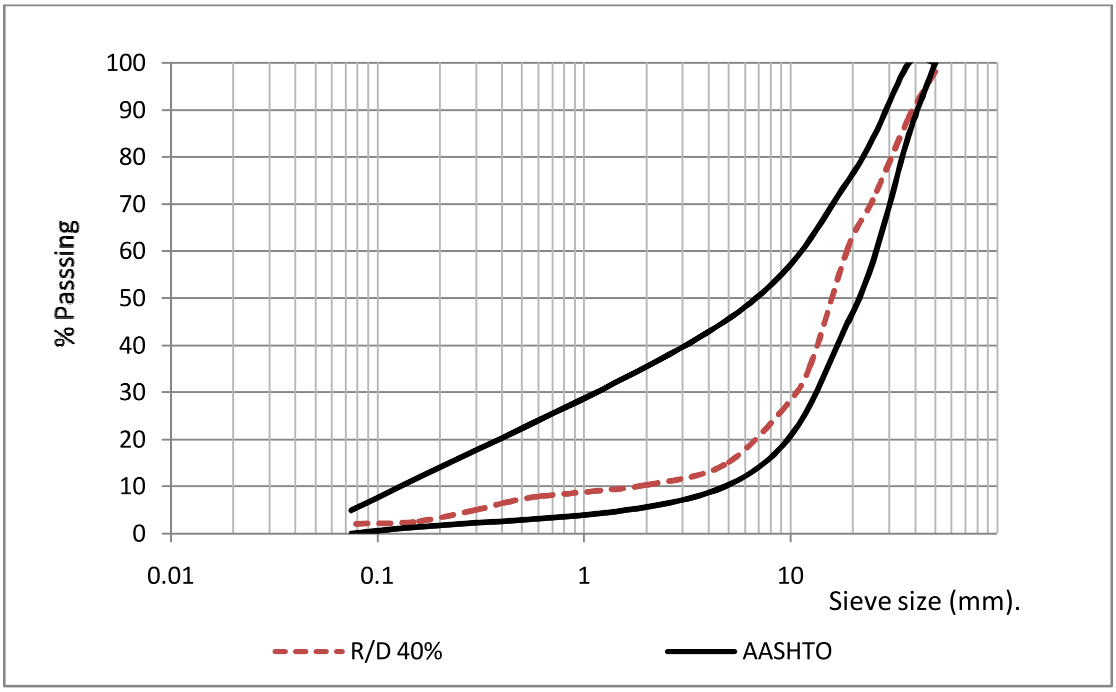

Figure A.39 R/D 40% material gradation.

a.11.2 Atterberg limits

Table A.72 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/D 40% material.

Plastic limit	
Plastic limit	Non-Plastic

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C14	26.55	97.67	84.35	13.32	57.8	23.04	20.4
C9	47.04	123.14	109.43	13.71	62.39	21.97	18.45
At penetration 20mm water content 22.82							
L.L = 22.82%							

Plastic Index	-

a.11.3 California bearing ratio

Table A.73 shows results of CBR for R/D 40% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0	0.00	0.00
0.5	0.020	0.512	115.11	38.37
1	0.039	1.190	267.54	89.18
1.5	0.059	2.090	469.87	156.63
2	0.079	3.250	730.67	243.56
2.5	0.098	4.730	1063.40	354.47
3	0.118	6.730	1513.04	504.36
4	0.157	11.320	2544.96	848.34
5	0.197	15.470	3477.97	1159.34
5.095	0.201	15.882	3570.59	1190.22

CBR 0 .1	84
CBR 0.2	109.33
Take CBR	109%

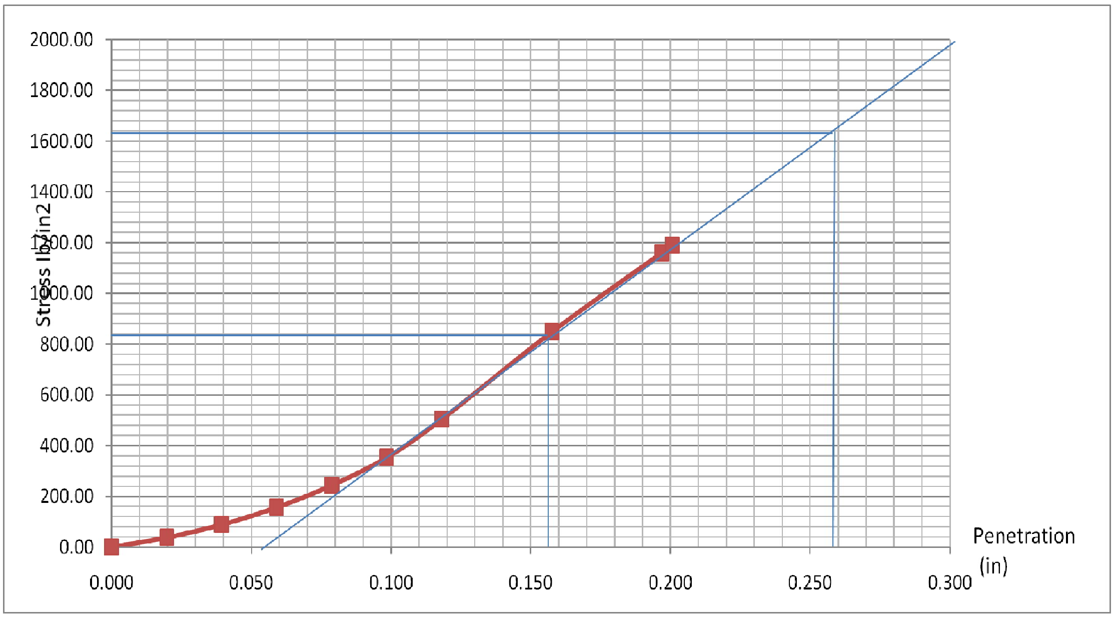

Figure A.40 R/D 40% material CBR

a.11.4 Modified Proctor

Table A.74 shows results of modified proctor compaction test for R/D 40% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
L9	32.75	358.3	344.19	4.53
L18	34.5	349.28	326.06	7.96
L16	30.77	398.76	366.86	9.49
L10	32.73	526.47	470.83	12.70
L11	32.6	519.87	447.91	17.33

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4920	9005	4085	1.92	1.840
4920	9240	4320	2.03	1.884
4920	9625	4705	2.22	2.023
4920	9720	4800	2.26	2.005
4920	9705	4785	2.25	1.920

mold volume	2123.7635
Pd max	2.03
W	10.2%

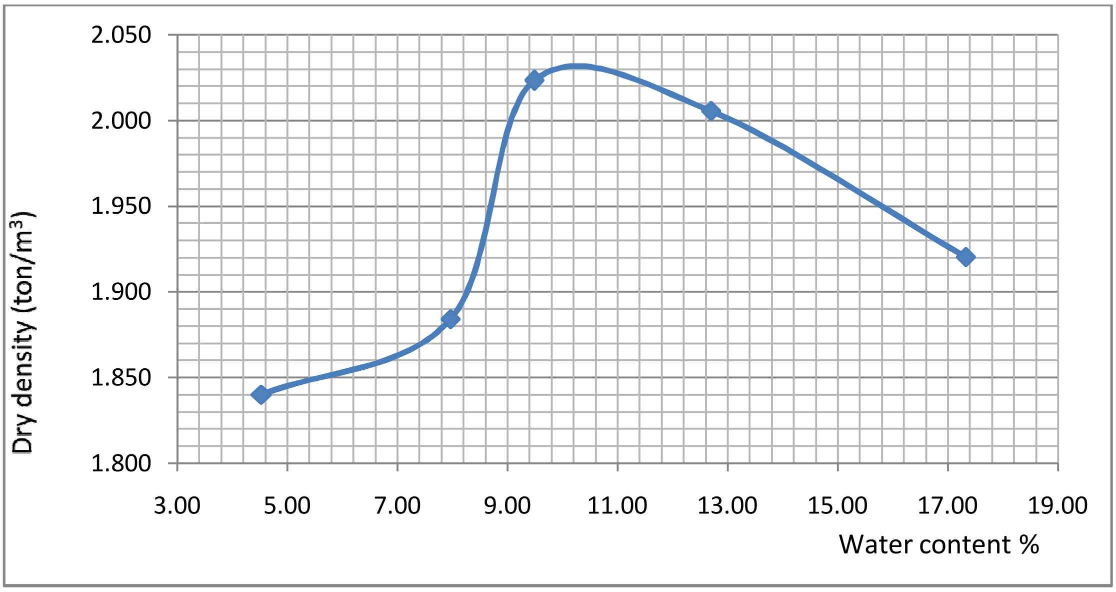

Figure A.41 R/D 40% material Proctor test

a.11.5 Specific gravity and Absorption

Table A.75 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/D 40% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	2015.43
dry wt.	1932.07
SSD supmerged	1169.93
Bulk specific gravity	2.29
Bulk specific gravity (SSD)	2.38
Apparent Specific gravity	2.54
Absorption	4.31%

Specific gravity & Absorption of fine aggregates	
Can wt.	114.24
dry wt. and can wt.	460.99
dry wt.	346.75
SSD wt.	361.3
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	1997.96
Bulk specific gravity	2.32
Bulk specific gravity (SSD)	2.42
Apparent Specific gravity	2.57

a.11.6 Sand equivalent and Absorption

Table A.76 shows results of Sand equivalent for R/D 40% material.

	Sample 1	Sample 2
Sand reading	104	102
Clay reading	158	155
Sand equivalent	65.82%	65.81%
Avarage Sand equivalent		65.81 %

a.11.7 Los Angeles test

Table A.77 shows results of Los Angeles test for R/D 40% material.

wt. of sample (g)	5000
wt. of losses (g)	1931.1
Los Angeles ratio	38.62%

a.12 R/D 50% material:

a.12.1 Gradation

Table A.78 shows results of sieve analysis test of R/D 50% material:

Wt. passing #4 : B	1570
Wt. retauned on #4	8385
Wt. mixed sample : A	9955

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Finall rate Passing
50	210			9745	97.89
37.5	1625			8120	81.57
25	2085			6035	60.62
19	915			5120	51.43
12.5	1930			3190	32.04
9.5	720			2470	24.81
4.75	900			1570	15.77
2		355	1215		12.20
1.18		140	1075		10.80
0.6		160	915		9.19
0.425		140	775		7.79
0.3		205	570		5.73
0.15		325	245		2.46
0.075		50	195		1.96

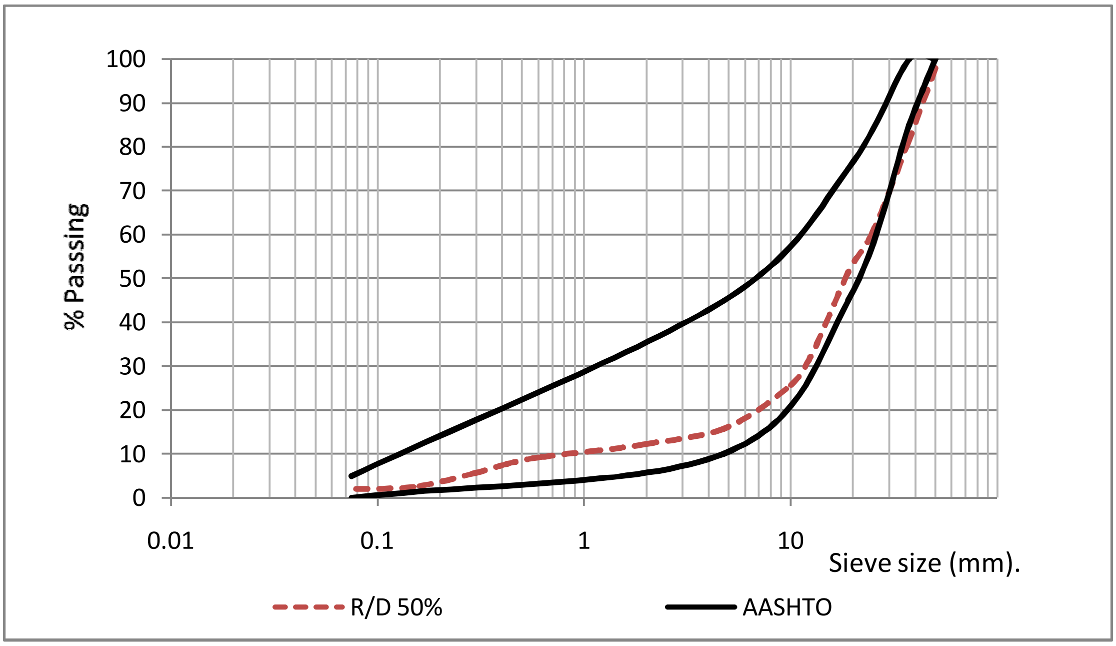

Figure A.42 R/D 50% material gradation.

a.12.2 Atterberg limits

Table A.79 shows results of Liquid limit (L.L), Plastic limit (P.L), and Plasticity Index (P.I) for R/D 50% material.

Plastic limit	
Plastic limit	Non-Plastic

Lquied limit							
can no	can wt.	wet soil+can wt.	dry soil+can wt.	water wt.	dry wt.	water content	penertration
C11	25.19	75.82	66.27	9.55	41.08	23.25	22.3
C29	24.53	88.42	77	11.42	52.47	21.76	19.2
C19	26.16	89.2	77.98	11.22	51.82	21.65	19
At penetration 20mm water content 22.15							
L.L = 22.15%							

Plastic Index	-

a.12.3 California bearing ratio

Table A.80 shows results of CBR for R/D 50% material

Area of Paston	2.999948286

Penetration (mm)	Penetration (in)	Piston Load (KN)	Piston Load (Ib)	Stress (Ib/in2)
0	0.000	0	0.00	0.00
0.5	0.020	0.590	132.64	44.22
1	0.039	1.250	281.03	93.68
1.5	0.059	2.110	474.37	158.13
2	0.079	3.230	726.17	242.06
2.5	0.098	4.440	998.20	332.74
3	0.118	5.630	1265.74	421.92
4	0.157	8.650	1944.69	648.24
5	0.197	11.930	2682.10	894.05
6.044	0.238	14.777	3322.17	1107.41

CBR 0 .1	58.5
CBR 0.2	77.33
Take CBR	77%

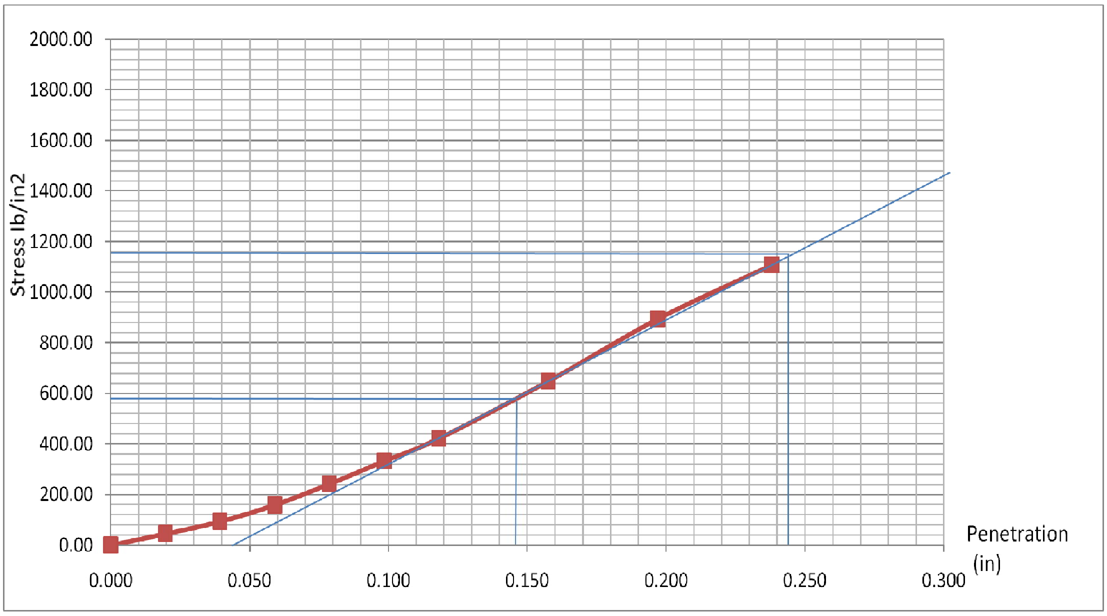

Figure A.43 R/D 50% material CBR

a.12.4 Modified Proctor

Table A.81 shows results of modified proctor compaction test for R/D 50% material

For water content				
Can no	wt. of can	wt. of wet soil	wt. of dry soil	water content
L12	36.41	433.39	413.55	5.26
N4	116.19	619.9	586.61	7.08
D30	113.26	819.66	755.75	9.95
G7	103.76	1042.02	932.76	13.18

For density				
wt. of mold	wt. of soil and mold	wt. of soil	wet density	dry density
4920	9170	4250	2.00	1.901
4920	9415	4495	2.12	1.977
4920	9675	4755	2.24	2.036
4920	9675	4755	2.24	1.978

mold volume	2123.7635
Pd max	2.036
W	9.90%

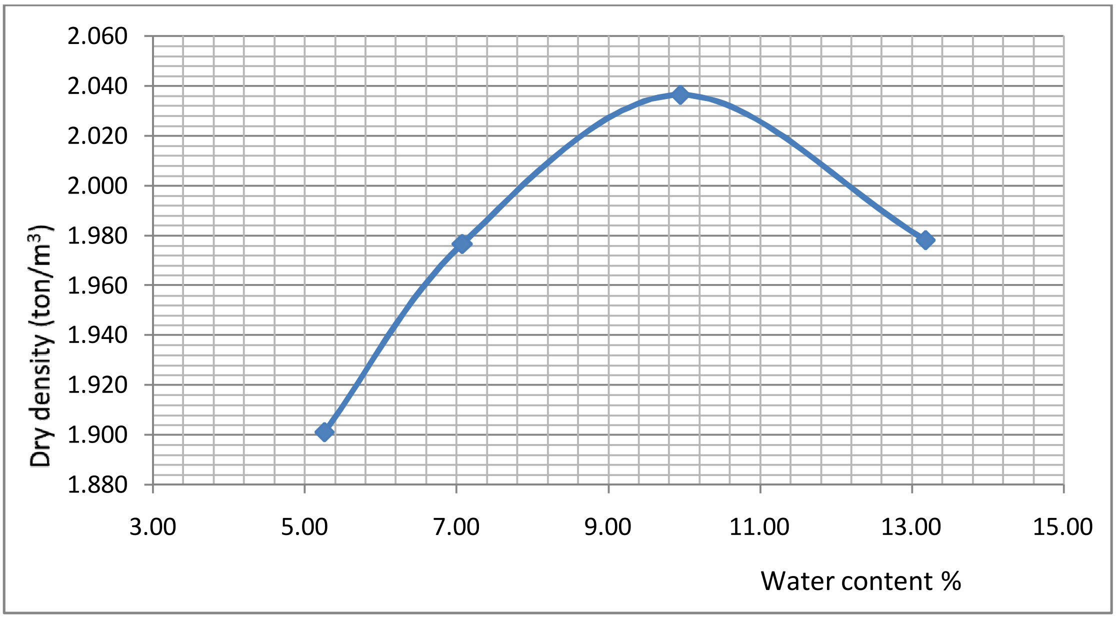

Figure A.44 R/D 50% material Proctor test

a.12.5 Specific gravity and Absorption

Table A.82 shows results of Bulk specific gravity, Bulk specific gravity in saturated surface dry condition (SSD), apparent specific gravity, and absorption for both fine and coarse aggregates of R/D 50% material.

Specific gravity & Absorption of coarse aggregates	
SSD wt.	1979.22
dry wt.	1894.74
SSD supmerged	1152.95
Bulk specific gravity	2.29
Bulk specific gravity (SSD)	2.40
Apparent Specific gravity	2.55
Absorption	4.46%

Specific gravity & Absorption of fine aggregates	
Can wt.	419.91
dry wt. and can wt.	834.16
dry wt.	414.25
SSD wt.	425
Bicnometer filled with water	1786.1
Bicnometer filled with SSD sample & water	2041.02
Bulk specific gravity	2.44
Bulk specific gravity (SSD)	2.50
Apparent Specific gravity	2.60

a.12.6 Sand equivalent and Absorption

Table A.83 shows results of Sand equivalent for R/D 50% material.

	Sample 1	Sample 2
Sand reading	97.5	102.5
Clay reading	146	161.5
Sand equivalent	66.78%	63.47%
Avarage Sand equivalent		65.12 %

a.12.7 Los Angeles test

Table A.84 shows results of Los Angeles test for R/D 50% material.

wt. of sample (g)	5000
wt. of losses (g)	1828.4
Los Angeles ratio	36.57%

a.13 Reclaimed Asphalt pavement:

a.13.1 Bitumen extraction

Table A.85 shows results of Bitumen extraction for Reclaimed Asphalt pavement

Can wt.	2437.1
Can + Sample wt. (Befor)	3419.7
Sample wt. (Befor)	982.6
Filter paper wt. (Befor)	13.1
Filter paper wt. (After)	14.1
Can + Sample wt. (After)	3364.2
Sample wt. (After)	927.1
Bitumen wt.	56.5
Bitumen Rate	5.75%

a.13.2 Gradation

Table A.86 shows results of sieve analysis test for aggregates used in RAP:

Wt. passing #4 : B	528.7
Wt. retauned on #4	395.11
Wt. mixed sample : A	923.81

Sieve dia.	Retained on #4 and above	Retained on less than #4	Comulative passing less than #4	Comulative passing #4 and above	Finall rate Passing
50	0			923.81	100.00
37.5	0			923.81	100.00
25	0			923.81	100.00
19	0			923.81	100.00
12.5	113.15			810.66	87.75
9.5	95.1			715.56	77.46
4.75	186.86			528.7	57.23
2		160	368.7		39.91
1.18		90	278.7		30.17
0.6		70	208.7		22.59
0.425		35	173.7		18.80
0.3		40	133.7		14.47
0.15		65	68.7		7.44
0.075		25	43.7		4.73

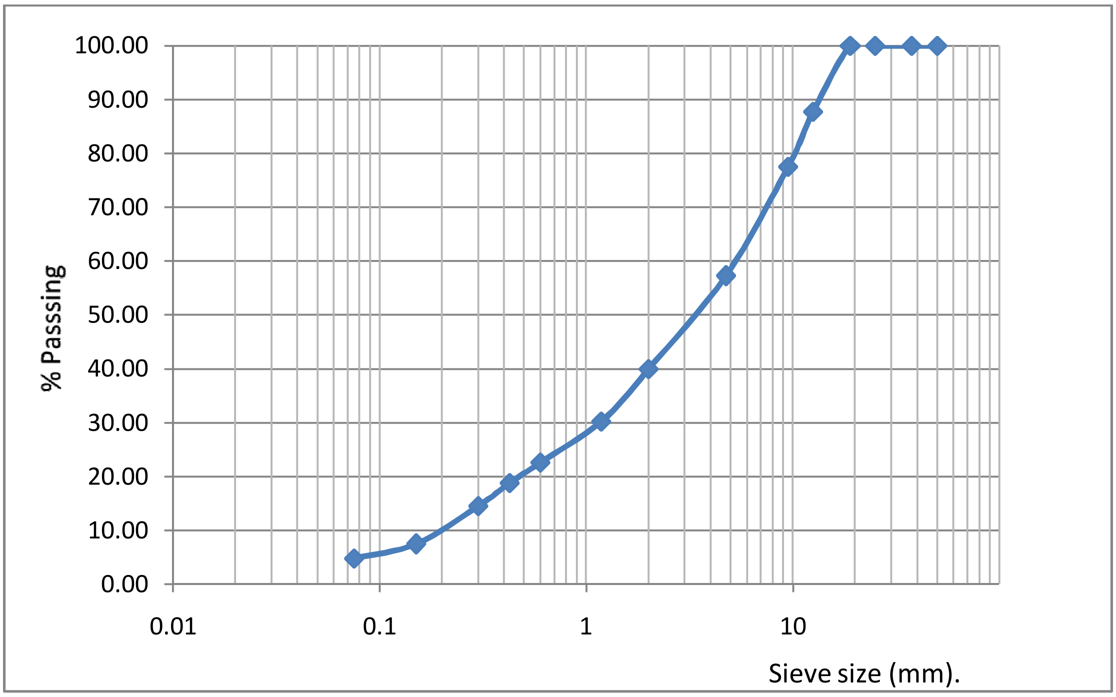

Figure A.45 Gradation of aggregates used in RAP.

Appendix B
AASHTO Specification

AASHTO (2010) DIVISION 300-- BASE COURSES

SECTION 304 --AGGREGATE BASE COURSE

Description

1.1 This work shall consist of furnishing and placing base courses on a previously prepared subgrade or course as shown on the plans or as ordered.

1.2 This work shall also include raising the grade of the edge of the roadway shoulders with crushed aggregate as shown on the plans or as ordered to match the grade of the pavement course placed on the shoulders or to provide a base for shoulder pavement.

Materials

2.1 General.

2.1.1 The materials shall consist of hard, durable particles or fragments of stone or gravel. Materials that break up when alternately frozen and thawed or wetted and dried shall not be used for aggregate base course materials. Fine particles shall consist of natural or processed sand. The materials shall be free of harmful amounts of organic material. Unless otherwise specified, the percent wear of base course material shall not exceed 50 percent as determined by AASHTO T 96, Grading A.

2.1.2 Crushed stone shall be processed material obtained from a source that has been stripped of all overburden. The processed material shall consist of clean, durable fragments of ledge rock of uniform quality and reasonably free of thin or elongated pieces.

2.1.3 Materials for glass cullet shall either be separated/recyclables received from a recycling facility permitted (pursuant to RSA 149-M:10) by the Waste Management Division of the Department of Environmental Services and/or materials certified for Direct Re-Use in accordance with Section 318 of the New Hampshire Solid Waste Rules.
2.1.3.1 Glass cullet shall meet the requirements of AASHTO M318.

2.2 Gradation. The required gradation of base course material shall conform to Table 1.

2.3 Sand. The maximum size of any stone or fragment shall not exceed three-fourths of the compacted depth of the layer being placed but in no case larger than 6 in. (150 mm).

2.4 Gravel. The maximum size of stone particles shall not exceed three-fourths of the compacted thickness of the layer being placed but in no case larger than 6 in. (150 mm).

2.5 Crushed gravel. At least 50 percent of the material retained on the 1 in. (25.0 mm) sieve shall have a fractured face.

2.6 Crushed gravel for shoulder leveling. This material shall consist of crushed aggregate for shoulders meeting the gradation requirements of Table 1 and shall then be mixed with at least 25 percent by volume of loam meeting the requirement of 641.2.1.

2.7 Crushed aggregate for shoulders. This material shall meet the gradation requirements of Table 1.

2.8 Gravel for drives. The material shall meet the requirements of gravel as shown in Table 1.

2.9 Crushed gravel for drives. The material shall meet the gradation requirements of either crushed gravel or crushed stone (fine) as shown in Table 1.

2.10 Crushed stone base course (fine gradation). Acceptable sand may be blended as necessary to obtain the proper gradation for the fine aggregate portion.

2.11 Crushed stone base course (coarse gradation). Acceptable sand may be blended as necessary to obtain the proper gradation for the fine aggregate portion.

Table 1 : Base course materials required gradation (AASHTO 2010)

Item No.	304.1	304.2	304.3	304.33	304.4	304.5	304.6
Item	Sand	Gravel	Crushed Gravel	Crushed Aggregate For Shoulders	Crushed Stone (Fine)	Crushed Stone (Coarse)	Crushed Stone (Very Coarse)
Sieve Size	Percent Passing By Weight						
6 in. (150 mm)	100	100	-	-	-	-	100
5 in (125 mm)	-	-	-	-	-	-	-
4 in (100 mm)	-	-	-	-	-	-	-
3 ½ in. (90 mm)	-	-	-	-	-	100	-
3 in. (75 mm)	-	-	100	-	-	85 – 100	60-90
2 ½ in. (63.5 mm)	-	-	-	-	-	-	-
2 in. (50 mm)	-	-	95-100	-	100	-	-
1 ½ in. (37.5 mm)	-	-	-	100	85 – 100	60 – 90	45-75
1 in (25.0 mm)	-	-	55 – 85	90 – 100	-	-	-
¾ in. (19.0 mm)	-	-	-	-	45 – 75	40 – 70	35-65
#4 (4.75 mm)	70 – 100	25 – 70	27 – 52	30 – 65	10 – 45	15 – 40	15-40
# 200 (0.075 mm) (In Sand Portion)*	0 – 12	0 – 12	0 – 12	-	-	-	-
# 200 (0.075 mm) (In Total Sample)	-	-	-	0 – 10	0 – 5	0 – 5	0-5

AASHTO Soil Classification

The AASHTO system of soil classification was developed in 1929 as the public road administration classification system. It has undergone several revisions, with the present version proposed by the Committee on classification of material for sub-grades and Granular type roads of the highway research board 1945 (ASTM designation D-3282; AASHTO method M145). According to this system, soil is classified into seven major groups: A-1 through A-7. Soil classified under groups A-1, A-2 and A-3 are granular material of which 35% or less of the particles pass through #200 sieve. Soil of which more than 35% pass through #200 sieve are classified A-4, A-5, A-6 and A-7. These soils are mostly silt and clay-type materials.

AASHTO Soil terminology:

Comes from AASHTO M145 "Classification of soils and soil-aggregate mixtures for highway construction purposes". Aggregate terminology comes from AASHTOM147, "Materials for aggregate and soil-aggregate sub-base, base and surface courses". Basic terms include:

- Boulders and cobbles: Material retained on a 75mm (3-inch) sieve.
- Gravel: Material passing a 75mm (3-inch) sieve and retained on a 2.00mm (No.200) sieve.
- Coarse sand: Material passing a 2.00mm (No.200) sieve and retained on a 0.475mm (No.40) sieve.
- Fine sand: Material passing 0.475mm (No.40) sieve and retained on a 0.075mm (No.200) sieve.
- Silt-clay: Material passing a 0.075mm (No.200) sieve.
- Silt fraction: Material passing a 0.075mm (No.200) sieve and larger than 0.002mm.
- Clay fraction: Material smaller than 0.002mm.
- Silty: Material passing the 0.075mm (No.200) sieve with PI<10.
- Clayey: Material passing the 0.075mm (No.200) sieve with PI>11.
- Coarse aggregate: Aggregate retained on the 2.00mm sieve and consisting of hard, durable particles or fragments of stone, gravel or slag. A wear requirement (AASHTO T 96) is normally required.
- Fine aggregate: Aggregate passing the 2.00mm (No.10) sieve and consisting of natural or crushed sand, and fine material particles passing the 0.075mm (No.200) sieve. The fraction passing the 0.075mm (No.200) sieve shall not be greater than two-thirds of the fraction passing the 0.425mm (No.40) sieve. The portion passing 0.425mm (No.40) sieve shall have a L.L<25% and PI <6%. Fine aggregate shall be free from vegetable matter and lumps or balls of clay.

Note that these definitions are AASHTO definitions. The table below shows the AASHTO soil classification system (From AASHTO M145). As shown in the following table, soil is divided into two parts:

1. Granular materials: are experienced by the 35% or less of passing the 0.075mm (No.200) sieve.
2. Silt clay materials: That more than 35% passing the 0.075mm (No.200) sieve.

Table 2 : AASHTO soil classification.

General classification	Granular Material (35% or less passing (No.200)							Silty-clay Material (35% or less passing No.200			
Group classification	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5 A-7-6
Sieve analysis % Passing 2.00mm 0.42mm .075mm	50max 30mx 15max	50max 25mx	51min 10max	35max				36 min		36 min	
Characteristic of fraction passing 0.42mm L.L P.I	6max	6max	N.P	40max 11max	41min 10max	40max 11max	41min 11max	40max 11max	41min 10max	40max 11min	41min 11min
Usual types of significant constitutent materials	Stone Fragment Gravel and sand		Fine sand	Silty or clay gravel and sand				Silty soils		Clay soils	
General rating as subgrade	Excellent to good							Fair to poor			

Appendix C

Asphalt Pavement Distresses

Asphalt pavement distresses

Pavement distresses are external indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses are cracks, rutting, and weathering of the pavement surface. Following is a review of some types of pavement distresses:

c.1 Fatigue (Alligator) Cracking

Fatigue (also called alligator) cracking, which is caused by fatigue damage, is the principal structural distress which occurs in asphalt pavements with granular and weakly stabilized bases. Alligator cracking first appears as parallel longitudinal cracks in the wheel paths, and progresses into a network of interconnecting cracks resembling chicken wire or the skin of an alligator. Alligator cracking may progress further, particularly in areas where the support is weakest, to localized failures and potholes. Factors which influence the development of alligator cracking are the number and magnitude of applied loads, the structural design of the pavement (layer materials and thicknesses), the quality and uniformity of foundation support, the consistency of the asphalt cement, the asphalt content, the air voids and aggregate characteristics of the asphalt concrete mix, and the climate of the site.

Figure c.1 Fatigue (alligator) cracking in asphalt pavement

c..2 Bleeding

Bleeding is the accumulation of asphalt cement material at the pavement surface, beginning as individual drops which eventually coalesce into a shiny, sticky film. Bleeding is the consequence of a mix deficiency: an asphalt cement content in excess of that which the air voids in the mix can accommodate at higher temperatures. Bleeding occurs in hot weather but is not reversed in cold weather, so it results in an accumulation of excess asphalt cement on the pavement surface. Bleeding reduces surface friction and is therefore a potential safety hazard.

Figure c.2 Bleeding distress in asphalt pavement

c.3 Block Cracking and Thermal Cracking

Block cracking is the cracking of an asphalt pavement into rectangular pieces ranging from about 30cm to 300cm on a side. Block cracking occurs over large paved areas such as parking lots, as well as roadways, primarily in areas not subjected to traffic loads, but sometimes also in loaded areas. Thermal cracks typically develop transversely across the traffic lanes of a roadway, sometimes at such regularly spaced intervals that they may be mistaken for reflection cracks from an underlying concrete pavement or stabilized base.

Block cracking and thermal cracking are both related to the use of an asphalt cement which is or has become too stiff for the climate. Both types of cracking are caused by shrinkage of the asphalt concrete in response to low temperatures, and progress from the surface of the pavement downward. The key to minimizing block and thermal cracking is using an asphalt cement of sufficiently low stiffness (high penetration).

Figure c.3 Block distress in asphalt pavement

c.4 Longitudinal Cracking

Non wheel path longitudinal cracking in an asphalt pavement may reflect up from the edges of an underlying old pavement or from edges and cracks in a stabilized base, or may be due to poor compaction at the edges of longitudinal paving lanes. Longitudinal cracking may also be produced in the wheel paths by the application of heavy loads or high tire pressures. It is important to distinguish between non wheel path and wheel path longitudinal cracking when conducting condition surveys; only wheel path longitudinal cracking should be considered along with alligator cracking in assessing the extent of load-related damage which has been done to the pavement.

Figure c.4 Longitudinal distress in asphalt Pavement

c.5 Pothole

A pothole is a bowl-shaped hole through one or more layers of the asphalt pavement structure, between about 6 inches and 3 feet in diameter. Potholes begin to form when fragments of asphalt concrete are displaced by traffic wheels, e.g., in alligator-cracked areas. Potholes grow in size and depth as water accumulates in the hole and penetrates into the base and subgrade.

Figure c.5 Pothole distress in asphalt Pavement

c.6 Rutting

Rutting is the formation of longitudinal depression of the wheel paths, most often due to consolidation or movement of material in either the base and subgrade or in the asphalt concrete layer. Another, unrelated, cause of rutting is abrasion due to studded tires and tire chains. Deformation which occurs in the base and underlying layers is related to the thickness of the asphalt concrete surface, the thickness and stability of the base and subbase layers, and the quality and uniformity of subgrade support, as well as the number and magnitude of applied loads.

Figure c.6 Rutting distress in asphalt Pavement

Appendix D

Photos Show the Method of the Work in the Laboratory

Figure (1) : Samples storing.

Figure (2) : Proctor compaction test.

Figure (3) : Cone tools for determining saturated surface dry condition.

Figure (4) : Determining specific gravity for fine aggregates by Pycnometer.

Figure (5) : CBR test device

Figure (6) : CBR molds

Figure (7) : Penetrometer device for Liquid limit test.

Figure (8) : Bitumen extraction test.

Figure (9) : Weighting samples.

Figure (10) : Sand equivalent test.