

(وَوَصَّيْنَا الْإِنْسَانَ بِوَالِدَيْهِ حَمَلَتْهُ أُمُّهُ وَهْنًا عَلَىٰ وَهْنٍ وَفِصَالَهُ فِي سِنِينَ عَامِينَ
 أَنْ اشْكُرْ لِي وَلِوَالِدَيْكَ إِلَيَّ الْمَصِيرُ (14) وَإِنْ جَاهَدَاكَ عَلَىٰ أَنْ تُشْرِكَ بِي مَا
 لَيْسَ لَكَ بِهِ عِلْمٌ فَلَا تُطِعْهُمَا وَصَاحِبِهُمَا فِي الدُّنْيَا مَعْرُوفًا وَاتَّبِعْ سَبِيلَ مَنْ
 أَنَابَ إِلَيَّ ثُمَّ إِلَيَّ مَرْجِعُكُمْ فَأُنَبِّئُكُمْ بِمَا كُنتُمْ تَعْمَلُونَ (15) يَا بُنَيَّ إِنَّهَا إِنْ تَكُ
 مِثْلَ قَالَ حَبَّةٍ مِنْ خَرْدَلٍ فَتَدُنُ فِي سَخِرَةٍ أَوْ فِي السَّمَاوَاتِ أَوْ فِي
 الْأَرْضِ يَأْتِي بِهَا اللَّهُ إِنَّ اللَّهَ لَطِيفٌ خَبِيرٌ (16) يَا بُنَيَّ أَقِمِ الصَّلَاةَ وَأْمُرْ
 بِالْمَعْرُوفِ وَانْهَ عَنِ الْمُنْكَرِ وَأَصْبِرْ عَلَىٰ مَا أَصَابَكَ مِنْ ذَلِكَ مِنْ عَزْمِ الْأُمُورِ)
 (17) وَلَا تُصَعِّرْ خَدَّكَ لِلنَّاسِ وَلَا تَمْشِ فِي الْأَرْضِ مَرَحًا إِنَّ اللَّهَ لَا يُحِبُّ كُلَّ
 مُخْتَالٍ فَخُورٍ (18) وَأَقْصِدْ فِي مَشْيِكَ وَاغْضُضْ مِنْ صَوْتِكَ إِنَّ أَنْكَرَ الْأَصْوَاتِ
 لَصَوْتُ الْحَمِيرِ (19))

سورة لقمان (14-19)

Dedication

To

The soul of my father for his watching me pushing and supported me through my life; God bless him,

My mother she is always there for me,

Sisters and brothers for their unlimited support,

Colleagues and friends wherever they are,

My family for inspire me and lightening my life.

Seifeldin

ACKNOWLEDGMENT

In the Name of Allah, the most gracious the most Merciful. Prays be to Allah alone, Lord of all the worlds.

Prays be to Allah who enable me to accomplish this work.

I am particularly indebted to my supervisor Dr. Awad Alkarim Mustafa for his help and his guidance, patients, assistance and advice during the period of this study, especially for giving me the confident that I can make a different.

In this respect I would like to express my deep appreciations to professor Galal Abd Allah Ali for his teaching us the meaning of commitment.

In this opportunity I express my great thanks and my deep appreciations to Dr. Sami Abd Allah for his continuous encouragement and guidance's I would like to express my appreciation to Ustaz Abas Badawi Laz for spent his whole life teaching us.

And deep thanks to Dr. Ahmed Mohammad Alsharif for his introducing me to the world of material and geotechnical engineer. I extend my great thanks to my colleague at Building and Road Research Institute University of Khartoum I specify my thanks to Mohammad Mohammad Ali, Abd Al Ilah Mohammad Hassan, and Abd Al Ilah Al Sidig.

Thanks to Engineer Nahla Hassan, Engineer Rafat Bitech and Mr. Jounge at National Highway Nationality laboratory.

I extend my thanks to Engineer Anwar Alzibare at Constructional and Environmental Labs. Centre Co. Ltd. Engineer Omer Shambat at Shirian Alshamal for Roads and Dams.

My great thanks to my colleague, Mohammad Alfadil, Wail Mustafa, Abu baker Ahmed Osman, Bashir Salaheldin Mohammad Isa and Ibrahim Mohammad Ahmed.

In this opportunity I express my respect and million of thanks are delivered to my family, my mother, sisters and brothers.

Thanks to all.

Table of contents

	Page
Quran teaches	I
Dedication	...II
Acknowledgment	...III
Table of contents	...V
List of figures	...VIII
List of tables	...IX
Abstract (in Arabic)	...X
Abstract (in English)	...XI
List of Abbreviations	...XII
Chapter One: Introduction	
1.1 General	...1
1.2 Transportation Demands	...1
1.3 Importance of Roads	...2
1.4 Problem Statement	...3
1.5 Justification	...4

1.6	Objectives	...5
1.7	Research Methodology	... 5
1.8	Research Obstacles	...6
1.9	Thesis Structure	...7

Chapter Two: Literature Review

2.1	General	...8
2.2	Historical Review	...8
2.2.1	Background	...8
2.2.2	Historical Milestone	...10
2.3	Modern Asphalt Usage	...12
2.3.1	Asphalt	...12
2.3.2	Uses of Asphalt in Sudan	...14
2.3.3	Terms Relating to Asphalt and Its Uses	...15

Chapter Three: Asphalt Review

3.1	General	...26
3.2	Asphalt Production	...26
3.3	Refining Crude Petroleum	...28
3.3.1	Steam and Vacuum Refining	...28
3.3.2	Solvent Extraction Method	...29
3.4	Petroleum Asphalt types	...31
3.4.1	Asphalt Cement	...31
3.4.2	Cutback Asphalt	...31
3.4.3	Emulsified Asphalt	...32

3.5	Characteristics of Asphalt Cement	...33
3.5.1	Consistency	...33
3.5.2	Purity	...34
3.5.3	Safety	...34
3.5.4	Durable, workable and weather resistant	...35
3.5.5	Cementitious property	...35
3.6	Asphalt Cement Specifications and Tests	...35
3.6.1	General	...35
3.6.2	Penetration Test	...38
3.6.3	Viscosity	...39
3.6.4	Absolute Viscosity	...42
3.6.5	Flash Point Test	...42
3.6.6	Thin Film Oven Test	...43
3.6.7	Rolling Thin Film Oven Test	...44
3.6.8	Ductility Test	...46
3.7	Superpave System	...48
3.8	Elemental Analysis	...50
Chapter Four: Laboratory Testing		
4.1	Study Samples	...52
4.2 .1	Consistency Tests	...52
4.2.2	Cementitious Property Tests	...52
4.2.3	Safety Tests (Flash and Fire Tests)	...53
4.3	Viscosity Tests	...53
4.3.1	Arithmetic Deduction for Absolute and Kinematic Units	...53
4.4	Tests Results and Analysis	...55
Chapter Five: Discussion and Analysis		
5.1	General	...60

5.2	Penetration Grade System in Sudan	...60
5.2.1	Advantages and Disadvantages of Penetration Grade System..	61
5.3	Viscosity Grade System	
5.3.1	Advantages of Viscosity Grade System	...62
5.3.2	Disadvantages of Viscosity Grade System	...63
Chapter Six: Conclusion and Recommendations		
6.2	Summary	...64
6.3	Recommendations	...64
References		...66

Appendix A: tables of Viscosity Tests and Specifications

Appendix B: Figures of Asphalt Tests and Specifications

List of Figure

Page

Figure 3-1: Trinidad Lake Asphalt ...27	
Figure 3-2: Main Types of Asphalt used in road construction ...30	
Figure 3-3: Penetration test apparatus ... 38	
Figure 3-4: A deck of Cards show stress shape ...40	
Figure 3-5a: Viscometer ...40	
Figure 3-5b: Asphalt Institute Vacuum Viscometer ...41	
Figure 3-6: Cleave land Open Cup (COC) ...43	
Figure 3-7: Rolling -Thin Oven Test (RTFO) ...45	
Figure 3-8: RTFO ...46	

Figure 3-9: a - b Ductility Test apparatus

...47

Figure 4-1: Schematic Illustration of Kinematic viscosity

For 11 samples of asphalt grade 60/70

...58

List of Tables

Table 4.1: Viscosity Grading System ASTM D3381

...54

Table 4.2: Results to asphalt source Egypt

... 55

Table 4.3: Results to asphalt source Saudi

... 55

Table 4.4: Results to asphalt source Iran
... 56

Table 4.5: Results obtained for samples (Egypt, Saudi and
Iran) ...56

Table 4.6: Results obtained for random samples of asphalt
...57 (unknown source) within year 2009/2010

Table 4.7: Results for asphalt random samples
...57

Table 4.8: Classifying asphalt to penetration and viscosity
grade ...59

□□□□□□□□

إهتمت الدراسة بتطبيق نظام اللزوجة في إختيار الأسفلت المستخدم في تشييد الطرق بالسودان والتي تخص المهندسين، الإستشاريين ، الم قاولين، الموردين والجهات الحكومية مثل الهيئة السودانية للمواصفات والم قاييس.

يستورد السودان الأسفلت حسب نظام الغرز من عدة مصادر مثل مصر ،السعودية ، إيران.

شملت الدراسة نبذة تاريخية عن إستخدامات الأسفلت وتطوره المستمر ، هذه النظرة التاريخية تساعدنا على معرفة موقع السودان من هذا التطور والإتجاه الذي يجب أن يسلكه في ما يتعلق بنظام إختيار الأسفلت.

الأسفلت مادة ثيرموبلاستيكية يعني أن صلابته تعتمد على درجة الحرارة ، فالصلابة تقل بإرتفاع درجة حرارة الأسفلت . هذه العلاقة بين الصلابة ودرجة الحرارة تختلف من أسفلت لآخر لنفس درجة الغرز حسب نوع المصدر وطريقة تكرير خام البترول. عليه من الواضح أنه يجب تحديد درجة الحرارة المناسبة لإجراء الأختبار لإختيار الأسفلت ومقارنته. فإختبار الغرز عند درجة حرارة C^{025} يعطي نوع معين مثلا (70/60) في نفس الوقت إختبار لزوجة حركية عند درجة حرارة C^{0135} لنفس الأنواع 70/60 تعطي صلابة مختلفة عند هذه الدرجة التي تساوي تقريباً درجة حرارة الخلط والفرش والمندلة.

أثبتت الدراسة أن الأسفلت ذو درجة الغرز 70/60 من مصادر مختلفة له خواص هندسية ولزوجة حركية مختلفة. أو صت الدراسة بتطبيق نظام اللزوجة في إختيار الأسفلت المستخدم في الخلطات الأسفلتية في السودان وذلك لمواكبة التطور في صناعة وتشييد الطرق.

ABSTRACT

This study reviewed the Viscosity Grading System to be adapted in Sudan. It concerns Engineers, Consultants, Contractors, Suppliers and Local Authorities involved.

The Asphalt imported to Sudan from different sources (Egypt, Saudi, Iran ...etc) according to penetration grade system.

The study reviewed the history of grading Asphalt and its uses. This review will assist us to knowing how far Sudan has come to and where it should be in long term so as grading and selecting asphalt are concerned.

Asphalt is a thermoplastic material, that is, its stiffness is dependent on temperature, stiffness decreases as temperature increases, this temperature verses stiffness relationship is different for asphalt based on the origin of the Petroleum Crude and/or method of refining. It is clear we should define a test temperature at which the grading will be done and asphalt compared, (Penetration grade system is done on 25⁰c and Viscosity Test is carried out on 135⁰c)

The study proved that same penetration grade of asphalt 60/70 from different sources has different stiffness and hence different engineering properties.

The study recommended adapting Viscosity Grade System in Sudan for selecting Asphalt to be used in HMA

List of Abbreviation

HMA	Hot Mix Asphalt
ASTM	American Society for Testing and Material
AASHTO	American Association of State Highway and Transportation Official
SHRP	Strategic Highway Research Program
TRL	Transportation Research Laboratory
AI	Asphalt Institute
PG	Performance Grade
VG	Viscosity Grade
API	American Petroleum Institute
RTFO	Rolling Thin Film Oven