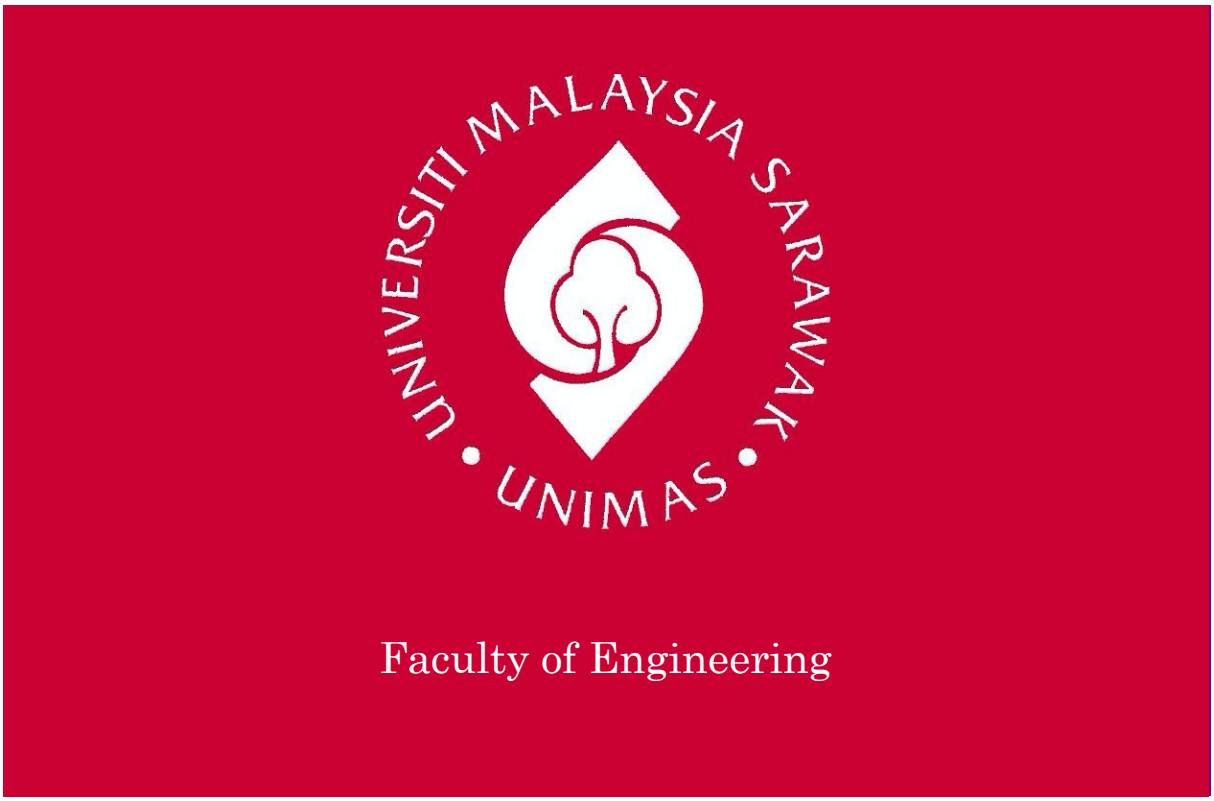

THE INVESTIGATION OF MECHANICAL AND PHYSICAL PROPERTIES OF GRANITE, LIMESTONE AND MICROTONALITE AGGREGATES

MAHATHIR BIN MOHD NOOR

Bachelor of Engineering with Honours

(Civil Engineering)

2020

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

Please tick (√)

Final Year Project Report	√
Masters	
PhD	

DECLARATION OF ORIGINAL WORK

This declaration is made on the 10th day of August 2020.

Student's Declaration:

I, MAHATHIR BIN MOHD NOOR, 56531, FACULTY OF ENGINEERING hereby declare that the work entitled THE INVESTIGATION OF MECHANICAL AND PHYSICAL PROPERTIES OF GRANITE, LIMESTONE AND MICROTONALITE AGGREGATES is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

10th August 2020
Date submitted

Mahathir bin Mohd Noor (56531)

Supervisor's Declaration:

I, RON ALDRINO CHAN@RON BUKING hereby certifies that the work THE INVESTIGATION OF MECHANICAL AND PHYSICAL PROPERTIES OF GRANITE, LIMESTONE AND MICROTONALITE AGGREGATES was prepared by the above named student, and was submitted to the FACULTY OF ENGINEERING as a partial fulfilment for the conferment of BACHELOR OF CIVIL ENGINEERING (Hons.), and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: _____ Date: 10th August 2020

(Ron Aldrino Chan @ Ron Buking)

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*****
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*****
☑ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirm with free consent and willingly declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitalise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature:_____ (10th August 2020)

Supervisor signature: _____ (10th August 2020)

Current Address:
185C, JALAN MERDEKA, KAMPUNG LINTANG, 93050, KUCHING, SARAWAK

Notes: ***** If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument is duly prepared by The Centre for Academic Information Services]

APRROVAL SHEET

This project report which entitled **"The Investigation of Mechanical and Physical Properties of Granite, Limestone and Microtonalite Aggregates"** was prepared and submitted by **Mahathir bin Mohd Noor (56531)** as a partial fulfilment of the requirement for degree of Bachelor of Engineering with Honours in Civil Engineering is hereby read and approved by:

10th August 2020

Ron Aldrino Chan @ Ron Buking

(Project Supervisor)

Date

THE INVESTIGATION OF MECHANICAL AND PHYSICAL PROPERTIES OF GRANITE, LIMESTONE AND MICROTONALITE AGGREGATES

MAHATHIR BIN MOHD NOOR

A dissertation submitted in partial fulfilment
of the requirement for the degree
of Bachelor of Engineering with Honours
(Civil Engineering)

Faculty of Engineering
University Malaysia Sarawak

2020

“Dedicated to my beloved Family, Lecturers, Friends and Doggos”

ACKNOWLEDGEMENT

Alhamdulillah, all praise to Allah SWT for His blessings and giving me the strength to complete the thesis successfully. Without His righteousness, it will be impossible for me to go through all the obstacles and allegations in completing the thesis given the tough situation at this moment.

First of all, I would like to express my utmost gratitude to my beloved supervisor, Mr. Ron Aldrino Chan @ Ron Buking as I am truly thankful for his never-ending support and guidance for the completion of this research. I would also like to thank you Mr. Lee Shyue Leong for his insightful assistance and constructive criticisms throughout my research. Special thanks goes to Mr. Saiful bin Edi and Mr. Mohamad Zaidi bin Serah for their endless help during the experimental work and test at UNIMAS' Highway and Concrete Laboratory. The same recognition also goes to the staffs of Cahya Mata Sarawak (CMS), Jabatan Kerja Raya Central Materials Laboratory and Jabatan Mineral dan Geosains Kuching, Sarawak for their kindness in giving me the opportunity in providing materials and equipment for my research.

I would like to extend my appreciation to my dearest family members especially my parents on their never-ending support, who always being there for me and giving me constant moral support and encouragement. Moreover, I also would like to take this opportunity to thank all of my close friends who have been there through thick and thin and support me throughout the journey completion of my research. I am overwhelmingly thankful for the affection and attentiveness I received.

ABSTRACT

Aggregates are the basic material for every construction that can help build a strong foundation, be it highways or railways. Sarawak's construction industry faces alarming granite shortages due to the massive demand arises from ongoing road construction projects. This research aims to investigate the mechanical properties of aggregate with the effect of wetting and drying cycles on different combinations of granite, limestone and microtonalite aggregates. Throughout this study, granite, limestone and microtonalite aggregates' mechanical and physical properties are studied with different types of aggregate combination design using granite as the main aggregates. Limestone and microtonalite aggregates are selected for modified aggregates as they have potential use in combination aggregate design to reduce the use of granite aggregates in industry. Laboratory work on the Elongation Index Test and Specific Gravity to determine the physical properties of aggregates was the first stage of laboratory testing. The second laboratory stage, the combination of aggregates, was tested for their mechanical properties with Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV) and Los Angeles Abrasion (LAA). The value of granite, limestone and microtonalite aggregate for both controlled and wetting and drying samples for AIV, ACV and LAA has met the standard requirement of Jabatan Kerja Raya, which is below 25% for AIV and ACV and below 45% for LAA. As a result, the combination of granite, limestone and microtonalite aggregates is acceptable and has the potential to be used in industry.

Keywords: Aggregates, Aggregate Impact Value, Aggregate Crushing Value, Los Angeles Abrasion, Granite, Limestone, Microtonalite

ABSTRAK

Batu adalah bahan utama bagi setiap pembinaan dimana batu boleh membantu untuk dijadikan asas yang kuat sama ada pada jalan mahupun laluan kereta api. Industri pembinaan Sarawak mengalami kekurangan bahan batu granite disebabkan oleh permintaan yang tinggi daripada projek pembinaan jalan yang sedang dijalankan. Tujuan kajian ini adalah untuk mengkaji properti mekaninal batu serta kesan lembab dan kering di atas batu dengan campuran batu granite, kapur dan mikrotonalite. Sepanjang kajian ini, batu granite, kapur dan mikrotonalite telah dikaji dalam properti mekanikal dan fizikal dengan reka bentuk campuran yang bebeza dengan menggunakan granite sebagai batu utama. Batu kapur dan mikrotonalite dipilih sebagai reka bentuk ubah suai kerana batu tersebut mempunyai kebarangkalian yang tinggi untuk digunakan sebagai reka bentuk campuran batu untuk mengurangkan pengunaan batu granite di dalam industri. Kerja makmal bagi *Elongation Index Test* dan *Specific Gravity* adalah untuk menentukan properti fizikal batu dimana ianya adalah fasa pertama dalam ujian makmal. Pada fasa makmal kedua pula, batu yang telah dicampur di uji bagi menentukan properti mekanikal batu dengan ujian *Aggregate Impact Value* (ACV), *Aggregate Crushing Value* (ACV), dan *Los Angeles Abrasion* (LAA). Hasil keputusan batu granite, kapur dan mikrotonalite bagi kedua-dua keadaan tetap, lembab dan kering untuk AIV, ACV, dan LAA telah mencapai piawaian yang telah ditetapkan oleh Jabatan Kerja Raya iaitu dibawah 25 peratus bagi AIV dan ACV dan dibawah 45 peratus bagi LAA. Kesimpulanya, keputusan campuran batu granite, kapur dan mikrotonalite diterima dan mempunyai potensi untuk digunakan di dalam industri.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	-	Asphalt Concrete
ACV	-	Aggregate Crushing Value
AIV	-	Aggregate Impact Value
ASTM	-	American Society for Testing Materials
BS	-	British Standards
CMS	-	Cahaya Mata Sarawak
JKR	-	Jabatan Kerja Raya
LAA	-	Los Angeles Abrasion
SG	-	Specific Gravity
UNIMAS	-	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Aggregate is a collective term used as an important medium to form composite materials (such as asphalt concrete and portland cement concrete) made from natural materials such as sand, gravel and crushed stone. In term of size, aggregate accounts for 92 to 96 per cent of Asphalt Concrete (AC) and about 70 to 80 percent of Portland cement concrete (Tom, 2010). In both flexible and rigid pavements, aggregate is also used for base and sub-base courses construction. Nowadays, aggregates can be naturally produced or manufactured. According to Pavement Interactive (2019), natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing.

Aggregates are the base material for every construction which can help to build a strong foundation, whether it is highways or railways. They have standard properties that will help to build a stable foundation. For long-lasting results, they bind the costly cement and other materials together. In most cases, aggregates are used to add strength to the composite material and they are also used for drainage applications due to their relatively high hydraulic conductivity quality. Fine aggregate is used in making thin concrete slabs or other structural members and where a smooth surface is desired; coarse aggregate is used for more massive members (Amy, 2018)

In Malaysia, road development has growth tremendously in the past decade. Road and streets are built to cater the demand of the uprising populations. According to the

specifications of Jabatan Kerja Raya (2016), in order to maintain the quality of the pavement, limestone aggregate cannot be used for wearing course demand. Thus, making the high-quality aggregate for asphalt pavement construction become an ongoing problem. Hence, the granite aggregates are reducing due to demand from the mega construction project.

Moreover, for mega road project, the amount of aggregate required is huge and most of the time the aggregates are left unprotected from the harsh weather and therefore maintaining the quality of aggregate become unobserved. Besides that, some of the stockpiles of aggregates are not covered since there is no warehouse storage provided by the contractor making the aggregates exposed to the weather of sunny and rainy day called weathering process. This weathering process can give a huge impact to the quality of aggregate. Using durable, tough and fatigue resistance aggregates is a primary objective in providing long-life pavement construction (Collis & Smith, 2001, Gondal et al., 2008). Therefore, the effect of wetting and drying is needed to be understand. Hence, in order to provide solution to these problems, research on different types aggregate combination can be performed and tested for their mechanical properties with wetting and drying effect.

1.2 Problem Statement

During construction, it has become a norm for mega road project construction to not fully protect the piles aggregate on-site hence exposing the aggregates to the effect of wetting and drying cycle. According to National Cooperative Highway Research Program Report, (1964) the adverse effects of segregation on aggregates handling, transportation, and storage are well recognized but no widely accepted engineering basis has been established for comparing one approach to another. Such segregation effects have led to a substantial loss of time, energy and resources in developing different forms of paving mixtures or constructing multiple building units with uniformly distributed aggregates. This can affect the aggregate used for the pavement layer which exposed to the weathering effect thus affecting the quality of aggregate. Moreover, the exposed aggregate from the worn off asphalt on pavement surface can be also affected by wetting and drying process. Therefore, in order to construct a strong pavement wearing course, high-quality aggregate is required but the granite sources in Sarawak is keen to decrease due to huge construction demand. Thus, a shortage of aggregate for road construction occurs.

Additionally, there is no past research conducted for the combination of aggregate and no establishment of standard specification for Malaysia for the mechanical and physical properties on the combination of aggregates. Hence, a study from need to be conducted in order to analyze the different type of aggregates combination for pavement design. From the past research, there is research gap that can be implemented in this research where a research on different types of aggregates combination can be performed and tested for mechanical properties for granite aggregate, limestone aggregate and microtonalite aggregate.

1.3 Objectives

The aim of this research is to investigate the mechanical properties of aggregate with effect of wetting and drying cycles on different combinations of granite, limestone and microtonalite aggregates. The objectives of this study are stated below:

- To investigate the mechanical properties of individual types of aggregate and combination of granite, limestone and microtonalite aggregate.
- To determine the durability of individual types of aggregate and combinations of different types of aggregate treated with wetting and drying cycles in water.

1.4 Significant of Study

This research contributes in the area of investigation of the mechanical properties of granite aggregate, limestone aggregate and microtonalite aggregate. The significant of the research are:

i. Investigation on the mechanical properties of standard aggregate, combination of different types standard aggregates and, combination of standard and substandard aggregates.
ii. Evaluation on the mechanical properties of standard aggregate, combination of different types standard aggregates and, combination of standard and substandard aggregates treated with wetting and drying cycles in water.

The output of this research will beneficial for the discovery of the mechanical properties of combine aggregates. Moreover, this research also focuses on the aggregate

shortage problem in mega road construction project. Hence, this research has the potential to solve to aggregate shortage problem experience in most construction project.

1.5 Scope of Works

This study focuses on the investigation of the physical and mechanical properties of granite aggregate, limestone aggregate, and microtonalite aggregate. Granite is used as high-graded controlled samples while limestone and microtonalite are used as redesigned samples for low-quality aggregates with appropriate design modifications.

Granite, microtonalite and limestone aggregates are tested for aggregate crushing value (ACV), aggregate impact value (AIV) and Los Angeles abrasion (LAA). Besides this, combination of these three different types of aggregate with different percentages will also tested for its ACV, AIV and LAA.

For the purpose of durability test, granite, microtonalite and limestone aggregates will be treated with wetting and drying cycles using water as solution and tested for ACV, AIV and LAA. Moreover, combination of these three different types of aggregates with different percentages will also treated with wetting and drying cycles using water as solution and tested for ACV, AIV and LAA. The ratio of aggregates combination will be 75:25 and 50:50 using granite aggregate as the high-graded controlled samples while limestone and microtonalite aggregate used as modification samples.

1.6 Thesis Organization

This thesis is organized into five chapter as indicated below:

- Chapter 1: Introduction
  - This chapter consists of introduction, problem statement, significant of study, objectives and scope of works
- Chapter 2: Literature Review
  - This chapter consists of basic information of pavement structures, geological structure of Sarawak, types of aggregate, and past research on the durability of aggregates.
- Chapter 3: Methodology
  - This chapter consists of the used research materials, testing procedure (standard specifications) of physical and mechanical properties of aggregates, and mechanical properties of combination of different types of aggregate.
- Chapter 4: Result and Discussions
  - This chapter consists of result obtain from testing of Aggregate Crushing Value, Aggregate Impact Value, and Los Angeles Abrasion. This chapter also discuss on the data obtain on the testing
- Chapter 5: Conclusion and Recommendation
  - This chapter consists of conclusion on this research and the recommendation that can be done in order to improve the research in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter briefly discusses the overview of pavement, properties of aggregate, types of aggregate, standard aggregate and substandard aggregates such as granite aggregate, limestone aggregate and microtonalite aggregate. Besides that, the geological structure of Sarawak is also discussed. Moreover, the mechanical properties of aggregate such as aggregate impact value (AIV), aggregate crushing value (ACV) and Los Angeles abrasion (LAA) are also discussed. In addition, literature review of past researches on the mechanical properties of standard and substandard aggregates are highlighted.

2.2 Pavement

Aside from technology, the development of a country depends on the connectivity of places provided with by proper road networks. Roads are known as a main channel of transportation in order to transfer one thing from one point to another, as well as carrying goods and passengers. There are several types of pavement depending upon on the available resources and material used.

Flexible pavement is the most commonly used in the road construction which built using asphalt concrete (AC) as its main component. The structure of flexible pavement consists of course aggregate, fine aggregate, bitumen and filler. Aggregate take up approximately 90 to 95% by weight of AC (Fwa, 2006). Bitumen has been widely used in the construction of flexible pavements for a long time. According to Tom (2009), the design of flexible pavement is based on the standard for various number of load with any magnitude, the intensity of a load moderates as the given load is transferred downwards from the surface course by over feature of spreading over as the area increasing through

greater area carrying it deep enough into the ground continuous layers of the granular material as shown in Figure 2.1. Fundamentally, the road structure usually consists of three layer which is subbase, base and surface course. There are many types of pavement that varying depends on the materials used. The most commonly used are flexible pavement, rigid pavements and semi rigid pavements.

For the flexible pavement, asphalt concrete is commonly used in road construction due to its cheaper cost and suitability. Flexible pavement is known to be the most suitable pavement to be built. The composition and the main structure of flexible pavement entail with the surface course, binder course which mostly contains of bituminous binder, base course, subbase course, and subgrade course. Bitumen or asphalt layer is used as the wearing course in the flexible pavement to supports loads through bearing.

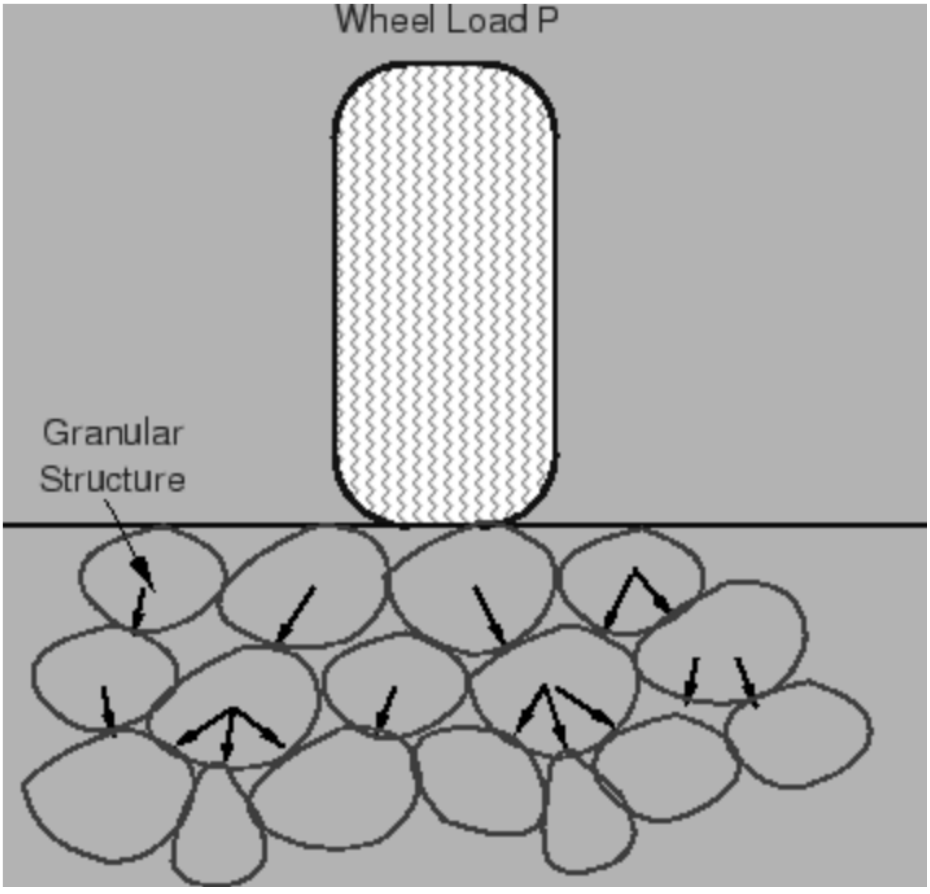

Figure 2.1: Load Transfer in Granular Road

2.2.1 Flexible Pavement

Flexible pavements are known to have low flexural strength. The topmost layer is of the flexible pavement is known as the surface course which has direct contact with the loads, mainly vehicle or pedestrian. Because of the direct contact with the traffic, suitable quality of aggregates and high dense bitumen is highly recommended for the construction of the surface course. According to Pavement Interactive, (2019) Aggregate is very important to avoid slippery accident to occur in all condition especially when the pavements is wet. As for the binder course, it is constructed by using aggregates and bitumen, but the quality required is less compared to the surface course. In general, the binder course will take up a thickness of about 50 to 100mm (The Constructor, 2019). The base course is the most vital layer of pavement structure and its main job is to disperse the loads from the top layer to the beneath subbase and sub-grade layers. The base course keeps and maintains the structural support for the pavement surface. To obtained strong base course layer, it is built with hard and durable aggregates which may either alleviated or granular or both. The sub-base course is constructed underneath the base course and the main functions of the subbase course are mostly as same as the base course. If the known area is equipped with strong and stiff sub-grade soil, thus, no requirement for subbase to be built. There are basically five layers of cross section in pavement (Alfaqawi, 2012). The typical cross section of a flexible pavement is shown as in Figure 2.2.

a) Sub-grade

   Sub-grade is one of the most important layers and consists of natural soil and the main purpose of the sub-grade is to sustain the loading from the layers above it. It is vital that at no time soil of sub-grace is overloaded. The sub-grade needs to be compacted to the required density, nearly the optimal moisture content.

b) Sub-base Course

   The Sub-base course is the layer of material below the base course and the main purpose of the sub-base course is to provide structural support, recuperate drainage and also to decrease the incursion of fines from the sub-grade in the pavement structure.

c) Binder Course

The binder course provides the mass of the bitumen base structure. Its main purpose is to dispense load to the base course. The binder course is commonly containing aggregates which having less bitumen and also does not required a high quality of material as compared to surface course.

d) Base Course

The base course is the layer underneath the surface of binder course and the main purpose of this course is to provides supplementary load distribution as well as to provides to the sub surface drainage.

e) Surface Course

Surface course is the utmost layer and has direct contact with the traffic loads and usually contains the highest quality of materials. It provides friction, smoothness, drainage, etc.

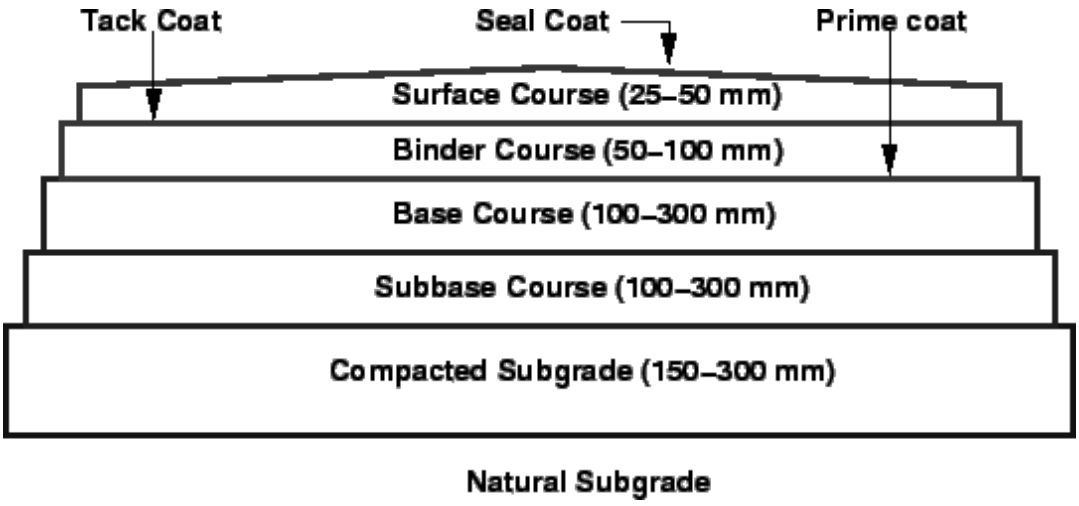

Figure 2.2: Typical cross section of a flexible pavement

(Source: Using Recycled Aggregate in Hot Asphalt Mixtures in Gaza Strip 2012)

2.3 Aggregate

According to Pavement Interactive, (2019) aggregate is known as a classification of loose materials that can be used in construction such as sand, gravel and crushed stone. Fine aggregate usually consists of sand, crushed stone, or crushed slag screenings; coarse aggregate consists of gravel (pebbles), fragments of broken stone, slag, and other coarse

substances (Amy, n.d.). Most of them are sourced from quarries, pits and even can be taken from other places such as sea in some countries. According to HMA Pavement Mix Type Selection Guide, aggregate is also regarded as the most effective pavement materials particularly for the surface course. The durability of pavement is subjected to various conditions such as weather, impact load and imposed load from the vehicle. The top layer is known as asphalt pavement where is it exposed with the friction of tyre from the vehicle on the road. Aggregate also hold an important role in many fields especially in construction purposes, domestic commercial projects and as well used as composition materials in concrete and cement

The most common use of materials in the asphalt mixed design is granite aggregate, an igneous type of rock. According to Roberts et al, (2002) granite aggregate has some fair properties in hardness, resistance to stripping, surface texture and crushed shape. Therefore, granite aggregate is known for its properties and widely use in the pavement industry. There are few types of aggregate that can be used in pavement design which can be classified as marginal granular materials. Marginal granular materials that could be considered for use in the upper pavement layers can effectively be grouped within a five-tier system (TRL, 2002), as listed in Table 2.1

Table 2.1: Marginal granular materials group

Granular	**Remark**
Hard Rocks	Mostly containing materials that require crushing as well as processing but retaining properties that result in the material does not fully meeting the requirements of a crushed stone base.
Weak Rocks	Materials imitative from weakly cemented, poorly consolidated or partially worn parent deposits.
Natural Gravels	Transferred from residual soils and gravels not achieving the minimum material standards for natural gravel road base.