USE OF PLASTIC WASTE WITH LOCKHART LIMESTONE IN BITUMINOUS PAVEMENT

By

Awais Hikmat (01-161172-008)

Irfan Ali Shah (01-161172-012)

Zohaib Asif (01-161172-036)

Department of Earth and Environmental Sciences

Bahria University, Islamabad Pakistan

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A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement for the degree of B.S in Geology

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ABSTRACT

Geotechnical tests of aggregate are important to determine strength of aggregate for various purposes. Limestone is mostly used for the purpose of road construction because of its good strength. Different regions of Pakistan are rich with such durable limestone. Tests were conducted on Lockhart limestone to assess its ability to be used as road aggregate. Plastic was added with Lockhart limestone aggregates in the proportion of 5%, 7% and 10% by weight and laboratory test were performed on the plastic-coated samples. Results for 5%, 7% and 10% coated plastic samples are 6.05%, 9.5% and 15.2% respectively for aggregate crushing test while non-plastic-coated aggregate show 14.5% loss. Average value of impact test of non-plastic aggregate is 22.75%, while plastic coated aggregate show 5.79%, 6.19% and 7.08% values. Los Angeles abrasion test show 9.495%, 11.65% and 14.25%. Marshal stability test show 2841.75, 2973.75, 3150.25 and 3162.75 values for 5%, 7%, 10% and 15% plastic content while aggregate with no plastic show result of 2202.5. Penetration tests showed 56.5, 52.08 and 53.41 for plastic mixed bitumen while non plastic bitumen show value of 65.5. Bitumen without plastic showed value of 43.75 while plastic coated bitumen shows 53, 57 and 48 values. The results of non-coated and plastic-coated samples lies within the prescribed limits defined by standards (ASTM, AASHTO & NHA). However, plastic coated samples proved more resistant to crushing and therefore can contribute to enhancing the road life and performance Lockhart limestone showed good physical resistance to crushing which prove that they can be used for road construction purpose.

Acknowledgement

We are thankful to Almighty Allah, the most beneficent and the most merciful, for His boundless blessings with which we qualified to pursue this thesis despite living in one of the most unprecedented times in our history. Working on a thesis during COVID-19 was a unique experience with a number of challenges.

We are highly obliged to our supervisor Mr. Masood Anwar Assistant Professor, Department of Earth and Environmental Sciences, Bahria University Islamabad, for his guidance, cooperation, precious time and moral support to complete this dissertation with dedication.

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LIST OF ABBREVATIONS

HDPE: High Density Polyethylene

HKS: Hazara Kashmir Syntaxis

MKT: Main Karakorum Thrust

MMT: Main Mantle Thrust

ASTM: American Society for Standards and Material

AASHTO: American Association of State Highway and Transportation Officials

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Rocks are basic components when it comes to building and construction. For the construction of roads, these rocks are broken down to small fragments and mixed in different proportions along with binder and bitumen. The size of those fragments depends upon its application and type and layer of road that is being constructed. Different queries in Pakistan provide rocks for such purposes. Mostly limestone is preferred type of rock that is used for road construction.

Mega projects that need aggregate in huge amounts normally set up large quarries closer to the area of construction. This helps to save the transportation cost. The life of a quarry depends on markets demand.

Different tests on aggregate are carried out to get qualitative and quantitative information about rocks and their suitability in various applications. In Pakistan, most of smaller projects skip doing this quality assessment of rocks which ultimately leads to failure. Wear and tear of roads and frequent formation of potholes is a common issue faced by the roads in Pakistan. This issue can be resolved by using a good quality binder and bitumen which will enhance life of road. But such products are usually costly. Therefore, there is a rising need to replace aggregate binders with a cheaper and stronger alternate.

1.2 Plastic Waste

Plastic waste is a great threat to our environment and to humanity. Plastic is non-biodegradable material which if not disposed properly, can be harmful to both our biotic and abiotic environment. Burning plastic to dispose produces a lot of harmful fumes and substances that has a great negative impact on environment. Burying plastic is an option but plastic does not degrade even in a million of years. So, with time it pollutes groundwater resources. Scientists have recently discovered microbes that eat away and digest plastic to produce waste that is not harmful. But this discovery has still not made any practical application. Mostly in our daily use HDPE (High Density Polyethylene) plastic is used (R.Manju et.al, 2017).

One last option that remains to get rid of this waste is the 3R rule. That is reuse, reduce and recycle. With time people are getting more and more aware of plastic pollution, and thus are more inclined towards using recycled products.

1.3 Road Construction

Roads provide accessible and easy routes to different regions of world and connect developing and rural areas. Good roads not just connect but also save travel time.

Different types of roads exist, and all these roads are constructed by varying methods using some specific proportion of aggregate, binder, cement and bitumen. A road usually consists of multiple layers when that make up the cross section of a road (Joseph, 1989).

Topmost layers of road are directly in contact with wheel and is subjected to most wear and tear. therefore, this layer is banded with bitumen to enhance flexibility and strength. For this reason, top two layers are also called wearing surface. Underneath the wearing surface there is base course, which is subjected to great number of pressures, so it is important to use good quality material in this layer. Subbase comes underneath base course. Subbase distributes the load of vehicles evenly to the ground. Sub grade lies underneath subbase that is naturally occurring.

There are several parameters that must be selected very carefully when constructing roads. One of the most important parameters is selection of correct type and size of aggregate. Aggregate selection is the first step involved in road construction. Geotechnical tests are performed on aggregate to assess the rocks strength and other properties. Detail of these tests is given in chapter 3.

1.4 Aggregate Selection for Road Construction

It is a critical step to select the aggregate. A good quality aggregate can greatly influence the life of a road. One of the most important rock types that is used for the purpose of road construction is Limestone. Limestone is preferred choice because of its good strength, durability and abundance. Limestone is one of the oldest materials that man has been using. It is known to be the world's most versatile chemical. Burnt and hydrated lime has been used by mankind since centuries to stabilize roads and other passageways.

Limestone is very often used as aggregate in road construction while most of the sedimentary rocks are soft and have less strength therefore, they are used for embankment construction. Limestone has ability to create good bond with bitumen but limestone having low polished stone value results in slippery nature when wet. This can be dangerous as reduction of friction between wheels and roads can result in accidents. This problem is solved by combining limestone with different agents to increase its polished stone value. Moreover, low thermal expansion also makes limestone a suitable rock to be used in road construction.

1.5 Plastic as Binder in Aggregate

Mainly two different types of binders are used that is cement and bitumen. Bitumen, also known as asphalt cement, is viscous fluid having black or dark brown color. Bitumen has good sticking properties. At normal temperatures, it is solid but when heated, bitumen melts and flows like a liquid. Molten bitumen can be mixed with aggregate and cooled to provide a matrix to grains of aggregate. It binds aggregate together and thus can be used for construction of roads. To further enhance the strength of binding of bitumen with aggregate, plastic can be added. The pavement that has plastic mixed with bitumen shows not just increase in strength of road but also resistance to water.

1.6 Problem Statement

As Pakistan is growing from developing to developed country, it is also working to improve its infrastructure and road network. Pakistan has got huge number of deposits of aggregate throughout the country. But this aggregate is not properly tested before using and thus strength of aggregate is not evaluated. This results in roads that are more prone to wear and tear and have short life cycle. Another problem that our country faces is plastic waste. Plastic is burnt and buried which both methods are harmful for our environment. Scientists are continuously trying to find a way to tackle the problem of plastic disposal. We can overcome both of these problems by using plastic waste like shopping bags in road construction. Plastic can be added as a binder along with bitumen which enhances the strength of roads and also solves problem of disposing off waste.

1.7 Objectives

To investigate the geotechnical properties of Lockhart Limestone as an aggregate for road construction and its performance with plastic coating.

1.8 Methodology

Fieldwork was carried out to collect aggregate sample from Taxila. Sample was prepared by grading and laboratory testing was done on aggregate both for non-coated and samples coated with plastic in different proportions. Similar set of laboratory test were carried out for non-coated and coated aggregates.

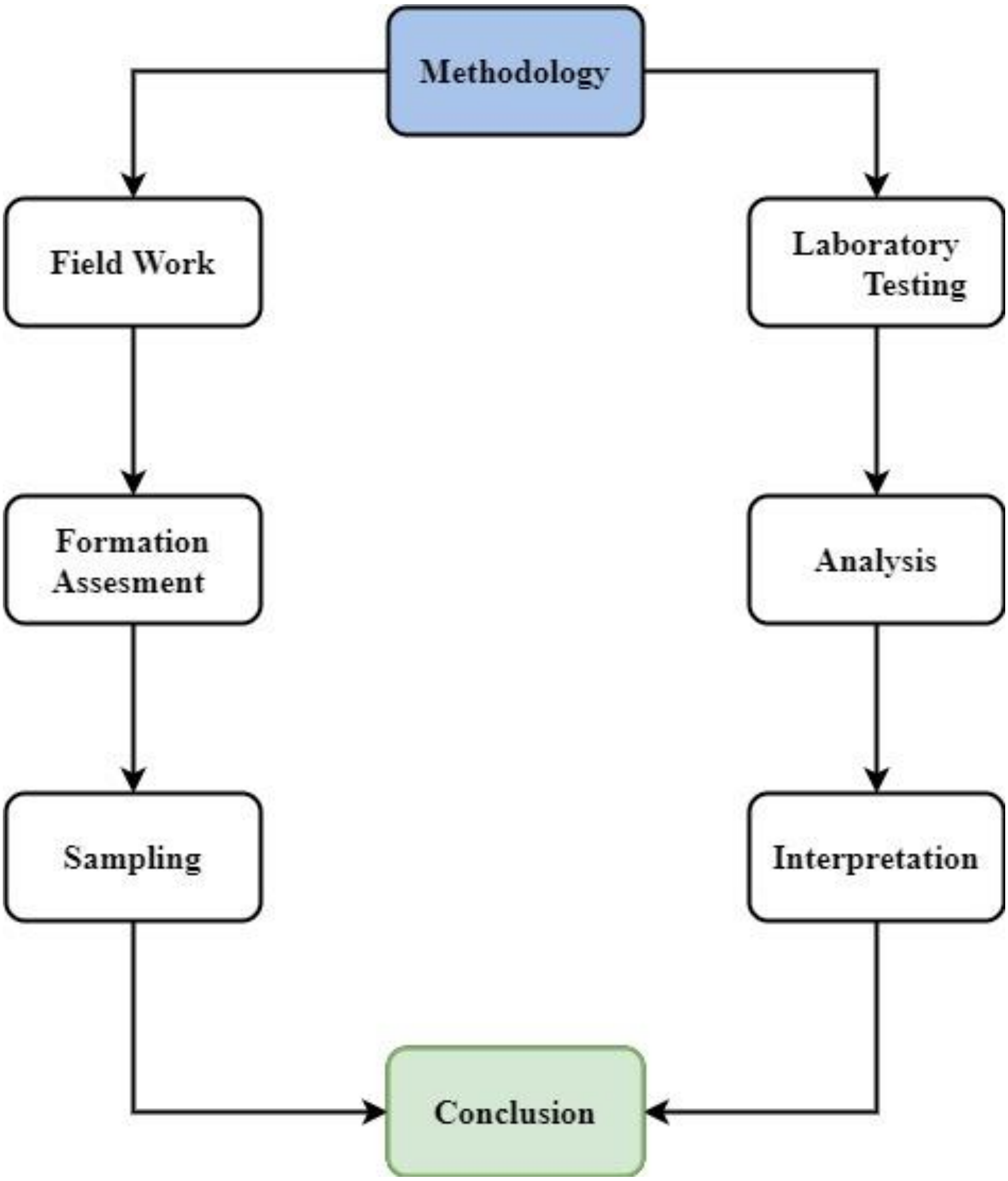

Figure 1.1. Methodology flow chart

1.9 Area of study and accessibility

There are many locations that can provide good quality aggregate. Twin cities of Rawalpindi and Islamabad get most of their aggregate supply from queries and crushers located in Taxila. The sample was collected from Margalla crusher that is located few hundred meters away from GT road. Coordinates of site of sample collection are **33.705257 N, 72.799907 E.**

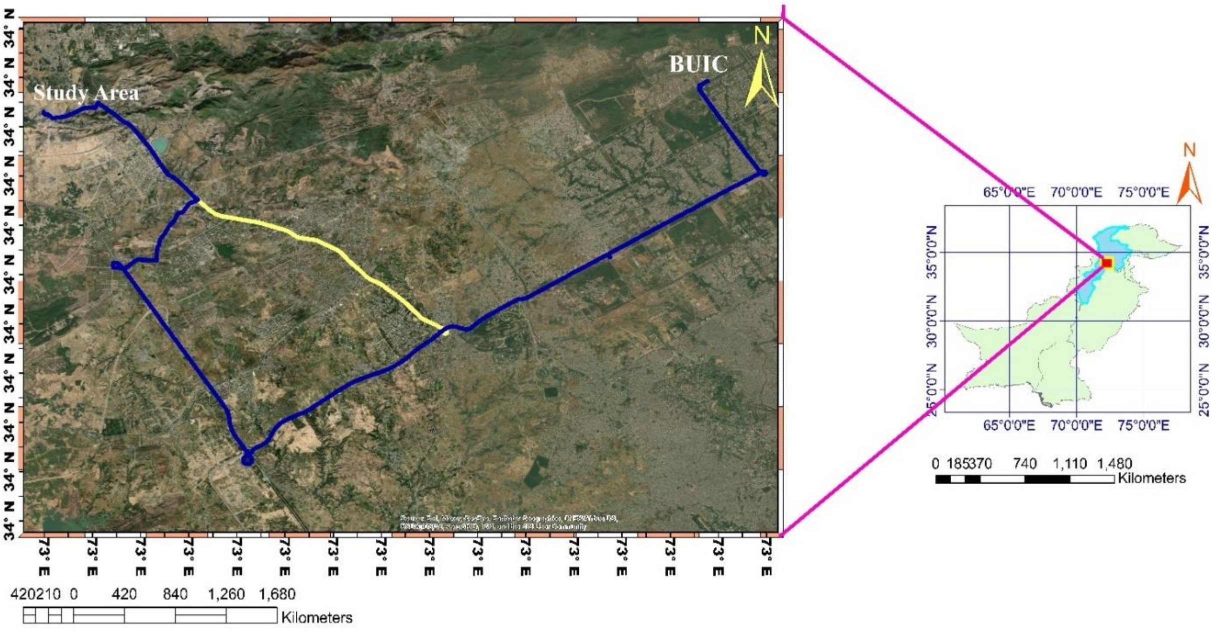

Figure 1.2. Accessibility map of study area (Source: ArcGIS)

CHAPTER 2

GEOLOGY AND TECTONICS OF PAKISTAN

2.1 Tectonic Settings

Pakistan a very important country in the context of Geology and Tectonics of Subcontinents. In context of stratigraphy and mineral deposits Pakistan has a clear edge in subcontinent and Asia. If we talk about the tectonics settings of Pakistan, then there are many important features which are present in Pakistan like Himalayas and its sub-components. Himalayas are formed due to the Northward movement of Indian Plate. The sub-components of Himalayas are:

i. Higher or Upper Himalayas
ii. Lesser Himalayas
iii. Sub Himalayas

The Indo-Pak subcontinent, which was earlier a member of Gondwanaland, split from the motherland around 130(M.Y) ago and drifted Northward. Intra-oceanic subduction produced a sequence of volcanic arcs such as the Chagai Arc, Kohistan-Ladakh, Nuristan, and Kandahar Arcs when the Indian Plate was drifting north around 55 million years ago in the Eocene. The Kohistan-Ladakh arc collided with Eurasia from 10-85 M.Y. ago when the back arc basin closed. The Kohistan arc developed an Andean Type passive margin after accretion to Eurasia. Around 65 to 60 million years ago, the northward advancing Indian plate collided with the Eurasian Kohistan-Ladakh margin. These activities were responsible for the formation of the Karakorum and Himalayan Ranges, as well as the sedimentation and evolution of sedimentary basins. They formed significant tectonic features, created magmatic sequences, and, most importantly, linked the associated mineral deposits.

2.1.1 Main Karakoram Thrust (MKT)

In Pakistan's northwestern province, it is a prominent feature. When the Karakoram Block in the north collided with the Kohistan Island arc in the south, it formed the Kohistan Island arc. In the NW Himalayas, a collision between continental India and KIA is believed to have happened between 50 and 55 million years ago. The northern boundary of the Eurasian Plate and the southern boundary of the Indian Plate are marked by MKT (400 km). MKT distinguishes KIA's Cretaceous Tertiary rocks from Karakoram Block's Late Paleozoic metasediments.

MKT is also known as the northern suture, and in the Ladakh region, it is known as the Shayok suture zone. Some of the mineral deposits occurring along the MKT zone are Iron ore, graphite, topaz, tourmaline, quartz crystals, ruby, epidote and tungsten.

2.1.2 Main Mantel Thrust (MMT)

MMT represents the southern boundary of KIA and Northern margin of Indian Plate (Kazmi and Jan, 1997). It was formed by subduction and subsequent collision of Indian Plate and KIA in Eocene time. This fault zone is having mantle related ultra-mafic, metavolcanic, meta-gabbros and phyllite. This zone is comprised of complex sequence of melanges which are composed of tectonic blocks of ophiolites, blue schist, greenschist and metasediments in matrix of sheared metasediments. Deposits of asbestos, chromite, peridot, emerald, magnesite, talc, soapstone, and minerals associated with gold are found in MMT fault zone (Kazmi and Jan, 1997).

2.1.3 Main Boundary Thrust

MBT is a fault mechanism that wraps around the HKS (Hazara Kashmir Syntaxis) in a hairpin formation (Kazmi and Jan, 1997). In the west, north, and east, MTB has taken Mesozoic rocks into faulted contact with Murree Fm. The MBT fault zone is made up of a series of thrust faults that separate the deformed and metamorphosed northern zone or hinterland from the deformed sedimentary southern zone or foreland in the NW Himalayan chain. Tight folding of MBT's hanging wall resulted in increased shortening. This may be the primary cause of the Margalla Hills' folds. The Jurassic Samanasuk Formation unconformably overlies Paleocene Hangu, Lockhart, and Patala Formations, which are underlying Eocene Margalla Hill Limestone, Chorgali, and Kuldana Formations in MBT's hanging wall stratigraphy.

2.2 Geology of Study Area

The study area is included in Hazara Basin. In the North of Hazara basin. In Taxila's limestone the ages vary from different geological periods, and the area is extended from Cherat to Abbottabad, Fig. 1 shows geological map of these areas, as well as uncovered rocks that display the structures that are visible in the region. Early to middle Paleocene limestone is predominantly nodular, with a dark grey hue dominating. Calcite veins are common in Lockhart Limestone.

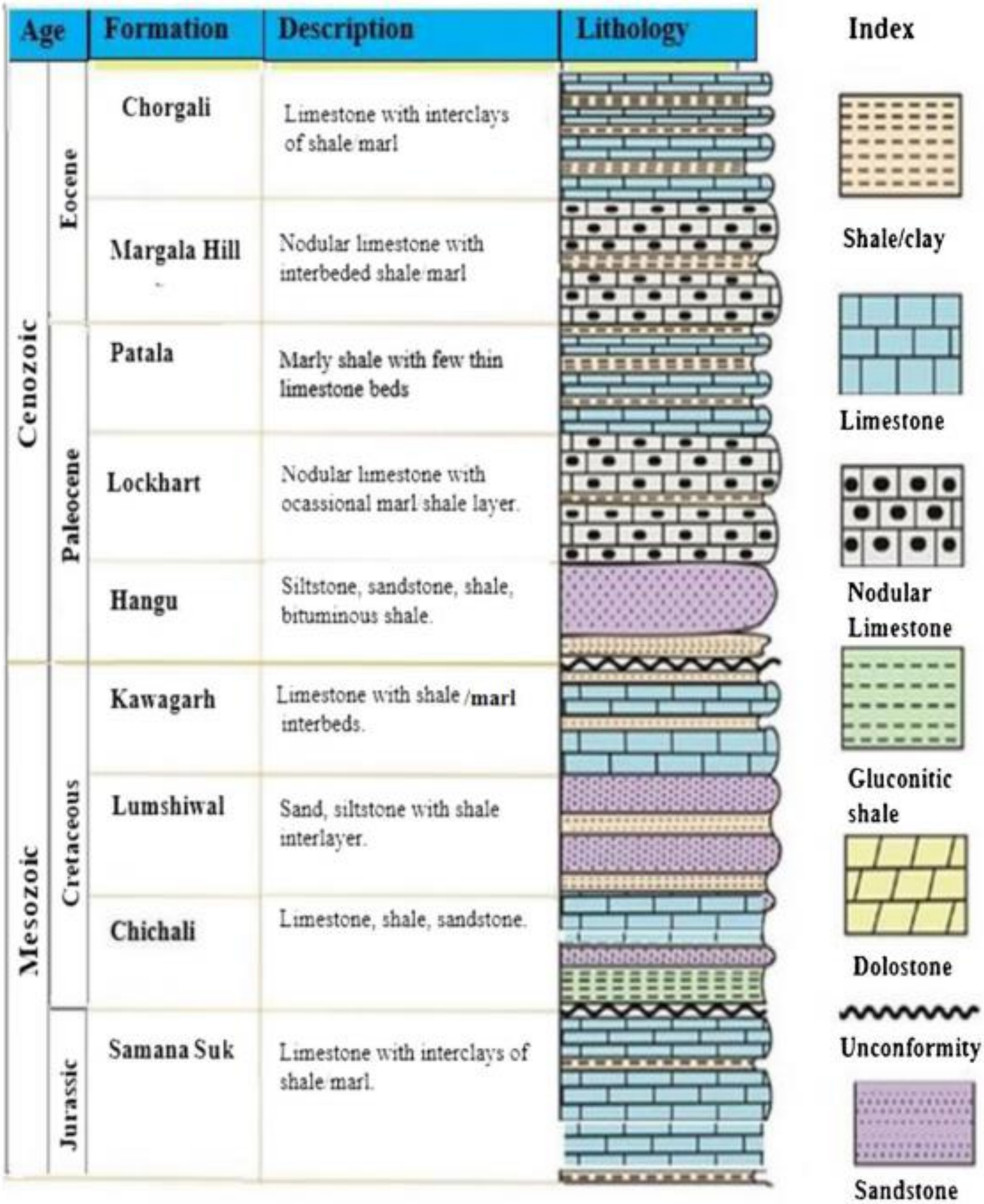

Figure 2.1. Stratigraphic Chart of study area and surrounding (Khan et al., 2018)

The approach has already been weathered. Margalla Hill Limestone is dark grey, thin to dense bedded, medium-grained calcareous with some marl from the Lower Eocene. Where the strata bedding is massive, calcite veins can be seen (Naeem, Khalid, M. Sanaullah, & Din, 2014). All the above discussed Formations are dominantly exposed in Taxila and Islamabad areas and its surrounding.

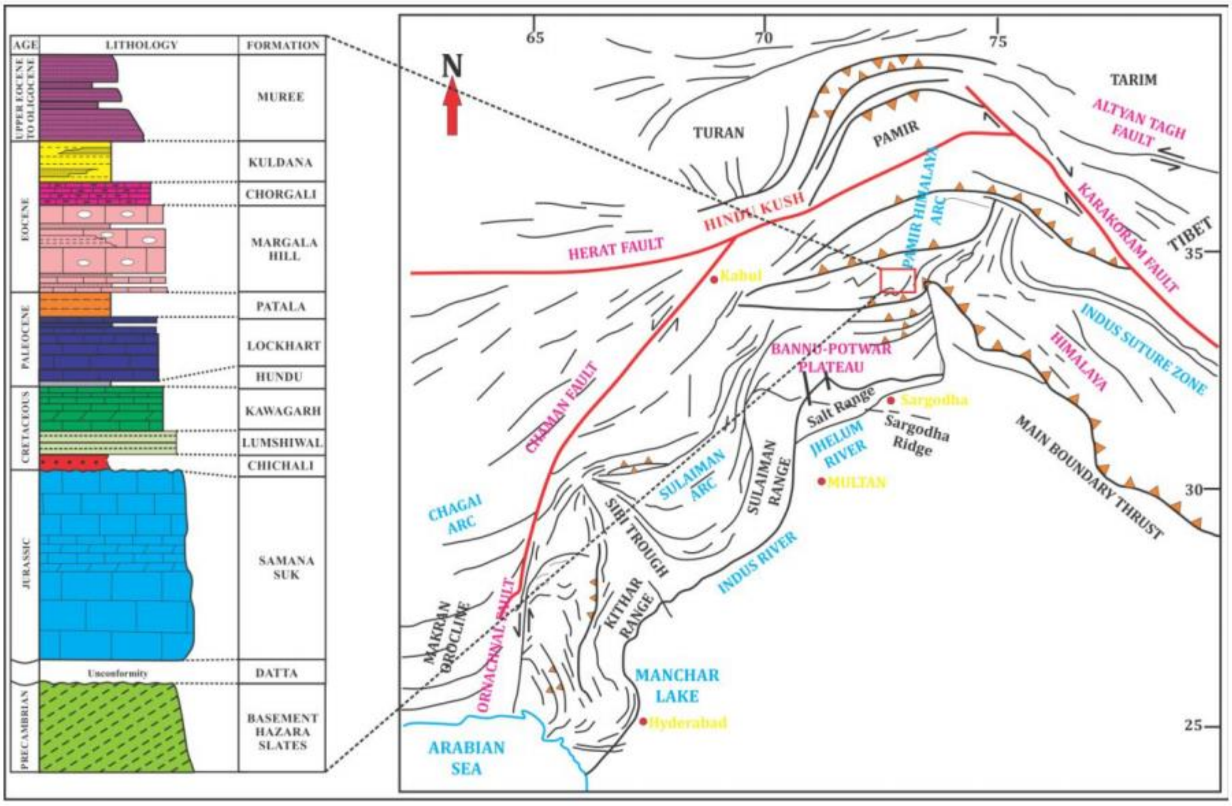

Figure 2.2. Tectonic map of Pakistan (Rahman et al., 2019)

2.3 Lockhart Limestone

Lockhart Limestone is an upper Paleocene rock on the basis of its fossils consist of mainly limestone (Mohibullah Khan et.al, 2018). The following fossils are reported from Lockhart Limestone consist of Lockhartia, Ranikothalia and Miscellanea of Paleocene age((Mohibullah Khan et.al, 2018).

Lockhart Limestone consist of large Foraminiferas like Miscellanea, Daviesina, Operculina (Wan X et. al, 2013). Lockhart Limestone act as a good source of aggregate for construction and other infrastructure projects in Islamabad, Rawalpindi and surrounding areas.

CHAPTER 3

MATERIAL AND METHODS

3.1 Aggregate Crushing Test (C131M)

3.1.1 Objectives

- To find the crushing value of an aggregate for road construction projects

- To find which material is suitable for which type of road.

3.1.2 Apparatus

The apparatus for said test as per IS is stated as: 2386-1963 (Part IV) (Kwame et.al, 2009). It consists of the following apparatus (Anon., 2018):

i. Measuring Cylinder
ii. Plunger
iii. Crushing test Machine
iv. Balance
v. IS standard sieves like 1/2 inch (12.5 mm), 8 number (2.36 mm)

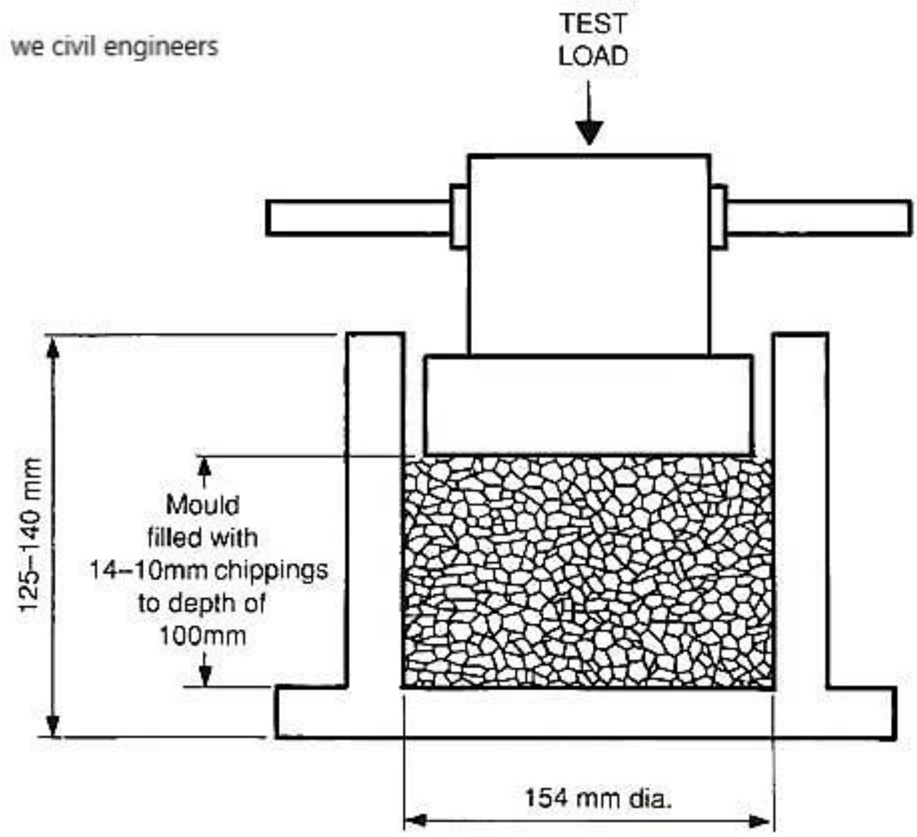

Figure 3.1. Aggregate crushing test apparatus

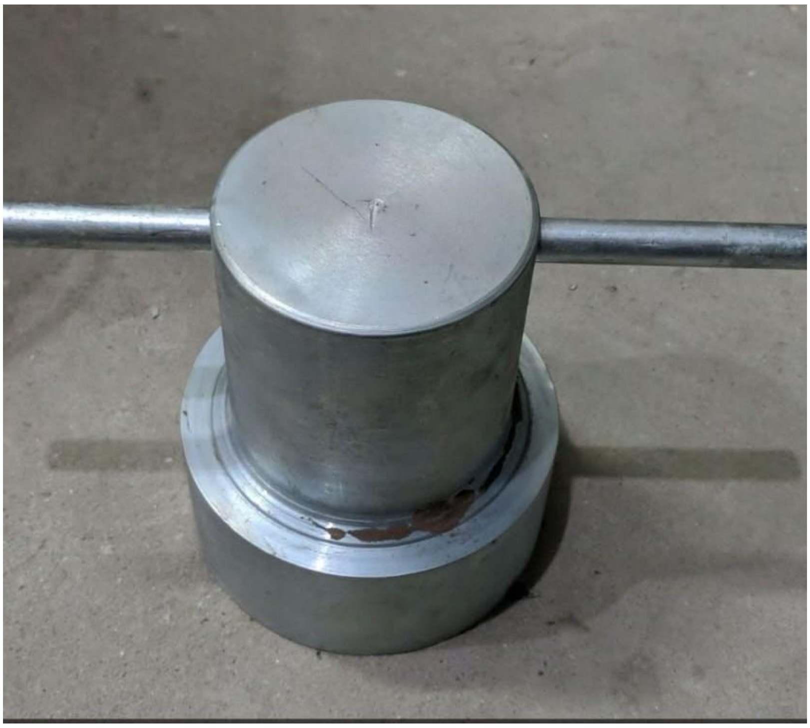

Figure 3.2. Plunger and Cylinder

Figure 3.3. Aggregate in cylinder after apply load in machine

Figure 3.4. Sieving of the load applied aggregate.

Figure 3.5. Aggregate crushing test machine

Figure 3.6. Crushed aggregate after sieving

3.1.3 Procedure

i. For sample, the material for the accurate test contains aggregate having size 10.0 mm to 12.5 mm. Oven dried the aggregate of 12.5mm passing and retained of 10mm of IS Sieve at temperature 100 to 110 °C for maximum 4 hours.

ii. Start filling in layers.

iii. First fill the first layer and the apply 25 strokes with tamping rod.
iv. Repeat the process by putting layers over one another.
v. The weight the aggregate as sample 1.
vi. Level the surface of the aggregate and the insert plunger.
vii. Put the whole apparatus with base plate in Aggregate crushing Machine.
viii. Start applying load in a machine of 400 Kilonewton or 40 ton. Then release the load.
ix. Sieve the sample by using sieve no. 8 (2.36 mm) and note the fraction passing as sample 2.
x. Using the formula as follows, find the crushing percentage, less the crushing percentage means that aggregate is more reliable for road construction.
    a. Aggregate crushing value = (sample 2/ sample 1) * 100
xi. The ASTM standard for wearing course surfaces shall not exceed then 45% (ASTM, 2016).

3.1.4 Precautions

i. The plunger has to be placed in the center yet straight on the aggregates. Place it in such way that it does not coincide the surface of the cylinder. This is to ensure that the whole pressure is exerted onto the aggregates.
ii. During filtration process of the components through sieve (2.36 mm), their weight shall be check before to avoid loss of fines. The original weight must be equal to the fines weight.
iii. The compression of aggregate should be done finely by tampering rod. Surface of cylinder must have fine tampering.
iv. And the aggregates must not touch the wall of cylinder.

3.2 Log Angeles Abrasion Test (C131M)

3.2.1 Objective

Log Angles Abrasion test is a test which subjects aggregate to constant wear and tear and in the end calculated hardness of aggregate and its resistance to breaking.

This test is important to carry because it tells us about the withstanding property of roads against external physical forces like crushing, deterioration, and disintegration.

3.2.2 Apparatus

i. Abrasion Test Machine
ii. 1.7 mm (Sieve no. 12)
iii. 11 iron balls
iv. Oven

3.2.3 Procedure

i. Weight the sample and note the reading as A.
ii. First weight the sample and then put the sample in a cylinder.
iii. Place the iron balls in a cylinder and start the cylinder rotating.
iv. Complete 500 rotation and 30 to 33 revolutions per minute.
v. After completion of 500 revolution, stop the machine and sieve the sample by using 1.7 mm sieve or sieve no. 12.
vi. Weight the retain sample of sieve no. 12 as B.
vii. Formula as follow (ASTM, 2016)

$$\text{Los Angeles Abrasion Test} = [(A-B)/A] * 100$$

Figure 3.7. Los Angles Abrasion Test Machine

3.3 Impact Test(C535)

This test is carried out to find out the impact value of road aggregates and assess the aggregate suitability in road construction on the base of impact value.

3.3.1 Working

Toughness of aggregate is its ability to resist any change due to external physical forces. When cars and especially heavy vehicles like trucks pass from the road, the friction between tire and road results in abrasion of road. Too much of this abrasion can results in degrading of road that eventually get potholes. Therefore, it is necessary to evaluate the aggregates resistance to impact beforehand.

3.3.2 Apparatus

For impact test the following standard apparatus are use (wecivilengineers, 2018):

i. Impact test machine
ii. Cylindrical steel cup

iii. Sieves: 12.5mm (1/2 inch), 10mm and 2.36mm (8 no.)
iv. Metal hammer of 14 kg weight.
v. Medal measuring cylinder
vi. Tamping rod 10mm diameter
vii. Electric Balance

Figure 3.8. Impact test machine

Figure 3.9. Applying impact test on sample

3.3.3 Procedure

i. Prepare the aggregate by grading and obtaining desired size. Wash the sample it and dry it for 4 hours at room temp.

ii. Place the base plate under cylinder. Then add aggregate in cylinder in three layers. Make sure to tamper aggregate with tampering rod after adding each layer.

iii. Place the cylinder at the balance in the impact test machine. Let the hammer fall 15 times at the rate of 1 impact per second.

iv. Take out the aggregate and pass it through 2.36 mm sieve. Note down passing weight as M2 and retained weight as M3.

3.3.4 Calculation

In each test, the weight of fines produced must be reported as a percentage of the entire sample weight.

Aggregate Impact Value = 100 x M2/M1

M1 is mass of test specimen.

M2 is mass of test specimen passing through 2.36 mm test sieve.

3.4 Penetration Test (D1586)

3.4.1 Objective

Penetration test is used to get some information about the consistency and density of bitumen. In this test we place a standard needle vertically on top of bitumen and calculate the distance which needle penetrated in tenths of millimeter. This test is performed under some specific temperature conditions. Loading pressure of needle is also a standard and is kept constant. This method can be used to categorize different types of bitumen.

3.4.2 Apparatus

i. Penetrometer
ii. Needle
iii. Container
iv. Water Bath
v. Thermometer for Water Bath
vi. Stopwatch
vii. Water

Figure 3.10. Penetrometer

3.4.3 Principle

It determines bitumen hardness or softness by measuring the depth in tenths of a millimeter that a typical loaded needle will penetrate vertically in 5 seconds.

3.4.4 Procedure

i. Heat the bitumen in oven to soften it.
ii. Place the soft molten bitumen in a container. Depth must be enough that 10 mm needle can easily penetrate completely if needed.
iii. Let the bitumen cool at room temp.
iv. Place the container with bitumen in a water bath with burner underneath. Use a thermometer to maintain the temperature of water which will ultimately keep the bitumen at proper temperature.
v. Touch needle at the top of bitumen such that needle hardly touched the bitumen.
vi. Start stopwatch and allow needle to penetrate in bitumen for 5 seconds. After 5

seconds stop the penetration and measure the length of needle that penetrated.

vii. This length is used to calculate the grade of bitumen and ultimately to categorize the bitumen.

viii. Repeat the experiment at least 3 times and calculate average value.

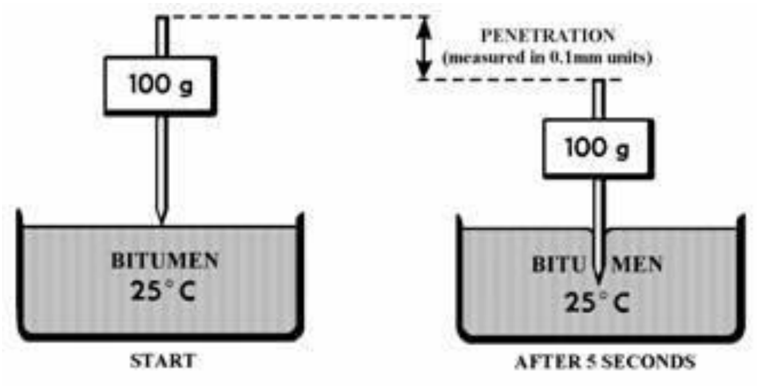

Figure 3.11. Needle Penetration in Bitumen

Table 3.1. Temperature conditions and Asphalt Grade

Temperature conditions	Asphalt Grade
Cold, mean annual air Temperature <7° C	80/100 Penetration
Warm. mean annual air Temperature 7 to 24° C	60/70 Penetration
Hot, mean annual air Temperature >24° C	40/50 Penetration

3.5 Softening Point Test (D36)

3.5.1 Objective

Softening point of a bitumen is used to find out its viscosity, to determine the temperature at which a bituminous binder must be heated to make it applicable to be used for different purposes. Ring and ball equipment is used to find out softening point.

3.5.2 Apparatus

i. Two steel balls each having diameter of 9.5 mm and weighs 3.5.

ii. Two brass rings having depths of 6.4 mm. The bottom and top inner diameters are 15.9mm and 17.5mm.

iii. Ball guides are required to aim the movement of steel balls towards the center.

iv. A support to hold rings in place and suspending thermometer. The gap between the bottom of the rings and the top surface of the support's bottom plate is 25mm.

v. Thermometer (100^{o}C range)

vi. A glass beaker of 85 mm diameter and a depth of 1220 manometer.

vii. Stirrer to mix.

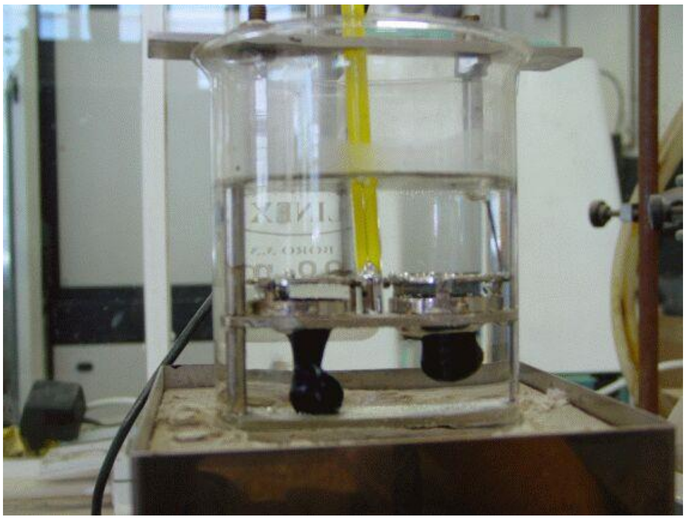

Figure 3.12. Ring and ball apparatus

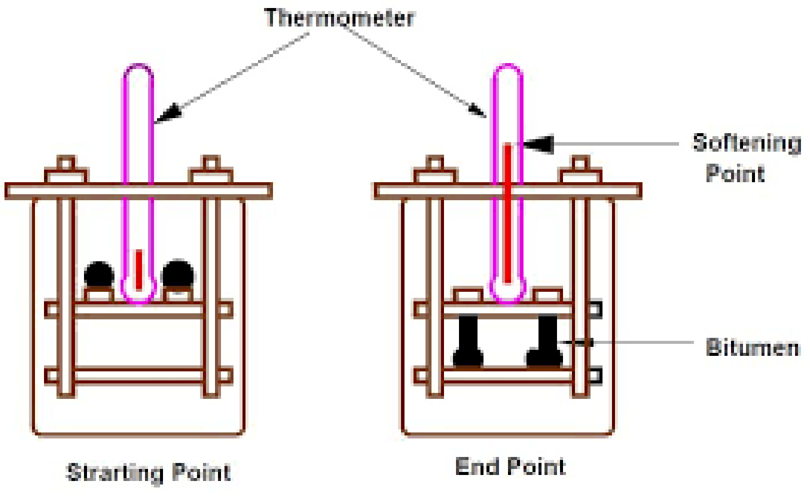

Figure 3.13. Apparatus of Impact test

3.5.3 Procedure

For test sample

i. Treat the substance to 75-100° C, above its softening point, and mix until total fluid is obtained which is free of air bubbles and water.

ii. Heat the rings to the temperature close to that of the molten substance and place the rings on a metal plate which is covered with combination of glycerin and dextrin in equal concentration.

iii. Let it cool under air and after 30 minutes, take a sharp, hot knife to remove extra material in the ring and level it. Set up the apparatus having rings, thermometer and ball guides in place.

iv. Fill the bath with distilled water until it reaches a height of 50mm above the rings' upper surface. 5° C should be the starting temperature.

v. Water is not used if softening point is expected to be more than 80°C. Is such case glycerin is used; the beginning temperature can be retained at 35° C. warm up the liquid at the pace of 5 ± 0.5 °C per minute.

vi. Bitumen gets less viscous as temperature is raised; this results the balls to sink in bitumen.

vii. As soon as one of the balls touches the bottom plate. A reading is taken.

viii. Average value is calculated by also letting the second ball touch bottom and calculate its temperature.

3.5.4 Precautions

i. The heating medium shall be distilled water.
ii. No vibrations are to be in contact with the equipment throughout the test.
iii. The thermometer's bulb should be around the same level as the rings.

3.6 Marshall Stability Test (D6927)

3.6.1 Objective

Marshal stability test is one of the most common tests used in road constriction. This test calculated the maximum load that a compacted sample of aggregate and bitumen can withstand. Flow is measured as a deformation in units of 0.25 mm between no load and maximum load carried by the specimen during a stability test. Marshal test aims to provide information about best binder and grade of bitumen that can be used for a specific size of aggregate for a specific purpose.

3.6.2 Apparatus

i. A 6.35 cm high and 10.16 cm diameter mould.
ii. Oven or hot plate
iii. Water bath
iv. Thermometer
v. Containers, mixing and handling tools
vi. A metallic base plate for mould
vii. A machine that can remove the compacted mould from the cylinder. Usually, a rod with flat end placed in a machine. The flat end is placed on top of mould and force is applied on rod to remove mould.
viii. A hammer that compacts the mould. Hammer must have a standard weight of 4.5 and must fall from a distance of 0.45 m.
ix. Compaction pedestal having a wooden block that has a capped plate. This helps to keep the mould assembly in place while compaction.
x. Breaking head consists of two cylindrical segments (upper and lower). The extended segment is placed on a base with two perpendicular guide rods that aid in

insertion into the higher test segment's holes.

xi. Loading Machine has a system of gears that allows it to raise upwards. A proving ring with a capacity of five tones is fastened to the machine's upper end, and the sample housed in the test head is placed in between the base and the proving ring.

xii. Flow meters is made up of a sieve and guide. It also has a gauge to note readings. A slight amount of frictional resistance slides the activating pin of the gauge into the guide sleeve. It has least count of 0.025 mm.

3.6.3 Preparation of Test Sample

i. 1.2 kg of aggregate is taken and heated in oven such that bitumen can be easily mixed and bonded.

ii. After the sample is heated, bitumen is added and mixed.

iii. Place the mixture of aggregate and bitumen in oven again and heat to achieve compaction temperature.

iv. Place a filter paper on bottom of mould and place the heated mixture into the mould.

v. Place the mould into compaction machine and apply 50 blows to compact the mould. Flip the mould and apply same number of blows on the other side of sample as well.

vi. Use the mould extractor to remove the mould from the cylinder.

vii. Cool the mould at room temperature.

viii. Sample’s mass in air and while immersed is utilized to calculate the void characteristics by measuring the density of the specimen.

ix. Specimens are cooked to 60^{o}C for 30-40 minutes in water bath. Alternately, samples can also be cooked in oven for 2 hours. The sample is withdrawn and positioned in the breaking head's lower section. The breaking head's top section.

3.6.4 Calculations

Result is calculated from following formulas.

Bitumen content (grams) =(W1-(W2+W3))/W1

Where:

W1 is the weight of the sample (grams)

W2 is the weight of the extracted mineral aggregate (grams)

W3 is the weight of the fine aggregate fragments (grams)

Percentage of bitumen content is calculated with respect wo either total weight of mix or with respect to total aggregate weight.

Bitumen content percent by weight of total mix = (bitumen content in grams / W1) x 100

CHAPTER 4

RESULTS AND DISCUSIONS

4.1 Aggregate Crushing Test

Table 4.1. Results of aggregate Crushing Test

AGGREGATE CRUSHING TEST				
Source (Lockhart Limestone)				
Sample. No	**Normal Samples of Aggregate**	**5% Plastic Coated Sample**	**7% Plastic Coated Sample**	**10% Plastic Coated Sample**
1	23	6.5	9	16
2	25	5.5	10	14
3	27	6.4	10	16
4	26	5.8	9	15
Average	**25.25**	**6.05**	**9.5**	**15.2**

According to standards, for Granular sub-base material according to AASHTO Specifications:

The coarse aggregate material retained on sieve No. 4 shall have a percentage of wear by the Los Angeles Abrasion (AASHTO T-96) of not more than fifty (50) percent (Nur Mustakiza Zakaria, 2018).

For surface course / wear course according to AASHTO:

The percentage of wear by the Los Angeles Abrasion test (AASHTO T-96) shall not be more than forty (40). Aggregate crushing value (ACV) when tested as per BS-812 (1990) shall not exceed 25% (Nur Mustakiza Zakaria, 2018).

For Asphalt concrete wearing course:

The percent of wear by the Los Angeles Abrasion test (AASHTO T 96) shall not be more than thirty (30) (Nur Mustakiza Zakaria, 2018).

The aggregate crushing value means the percentage passing by sieve no.8. In Normal sample which has no coating has a crushing value of 25.25 %. By adding by weight 5% of the plastic-coated aggregate, its crushing value decrease to 6.05%, by adding 7% plastic the aggregate crushing value is 9.5% and on the addition of 10% plastic by weight the crushing value increase 15.2%.

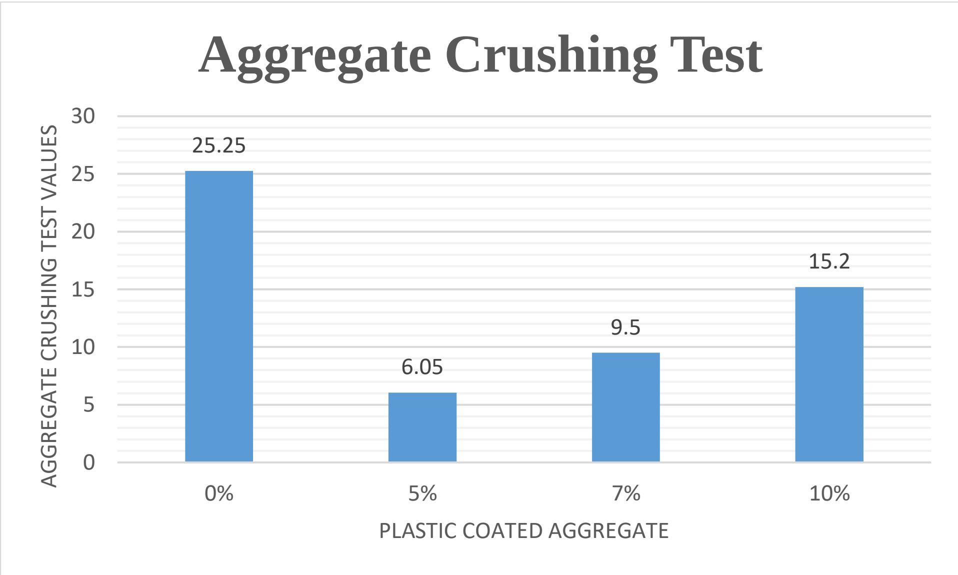

Figure 4.1. Aggregate Crushing Test result graphical representation

4.2 Impact Test

Table 4.2. Results of Impact Test

IMPACT TEST				
Source (Lockhart Limestone)				
Sample No	**Normal Samples of Aggregate (%)**	**5% Plastic Coated Sample (%)**	**7% Plastic Coated Sample (%)**	**10% Plastic Coated. Sample (%)**
1	15	5.80	6.20	7.10
2	16	5.90	6.18	7.15
3	13	5.70	6.22	7.05
4	14	5.75	6.15	7.00
Average	**14.5**	**5.79**	**6.19**	**7.08**

According to ASTM, the impact value should be less 30 percent (Nur Mustakiza Zakaria, 2018).

In the Impact test, we see the percentage of weight passing by sieve no. 8. By normal aggregate which is without coating has percentage passing on sieve no.8 is 14.5 and by adding 5% plastic by weight the result is 5.79%, on the addition of 7% plastic by weight the resulting drop to 6.19% and on the addition of 10% plastic, the result is 7.08. The results depict that on simple aggregate the impact value is high. But on 5 percent coated plastic aggregate the result is 5.79%. And again on 7 and 10 percent plastic, the result percentage is high as compared to 5 percent.

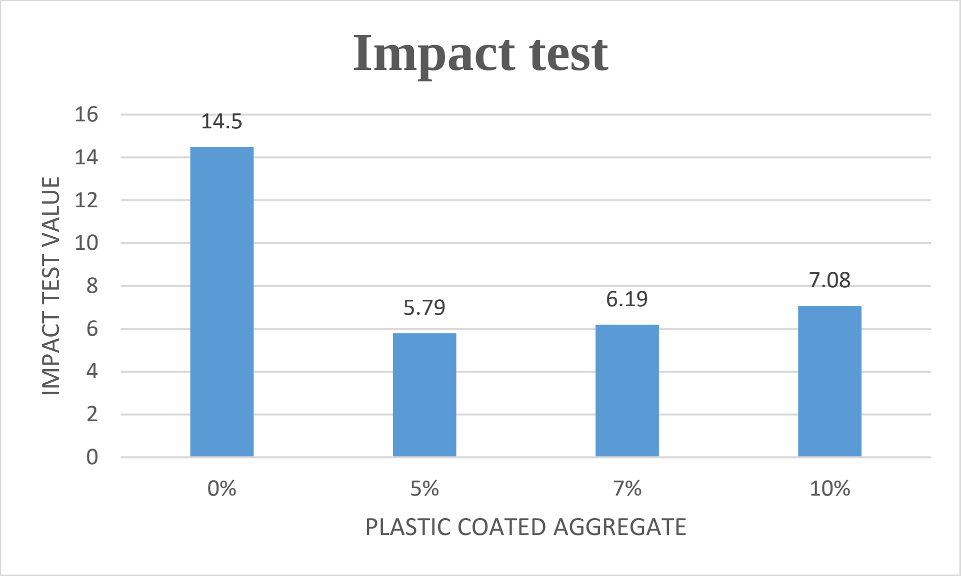

Figure 4.2. Impact Test result graphical representation

4.3 Los Angeles Abrasion Test

Table 4.3. Results of Los Angeles Abrasion Test

LOS ANGELES ABRASION TEST				
Source (Lockhart Limestone)				
Sample No	**Normal Samples of Aggregate**	**5% Plastic Coated Sample**	**7% Plastic Coated Sample**	**10% Plastic Coated Sample**
1	23	10	12	14
2	21	9.5	11.6	15
3	25	9.58	11	15
4	22	8.9	12	13
Average	**22.75**	**9.495**	**11.65**	**14.25**

Los Angeles Test result shows the percentage passing by sieve no. 12. On simple aggregate, the LA result is 22.75%. On 5% plastic-coated aggregate the result is 9.495%, on 7% plastic-coated aggregate the result is 11.65% and on 10% addition of plastic, the result is 14.25%.

These all results depict that if we use simple aggregate there will be more possibility of abrasion of aggregate. And if we use plastic coated aggregate the result starts varying. So, on increasing the addition of plastic percentagewise by weight. So, this means that if we increase the amount of plastic to 10 percent the result will be better.

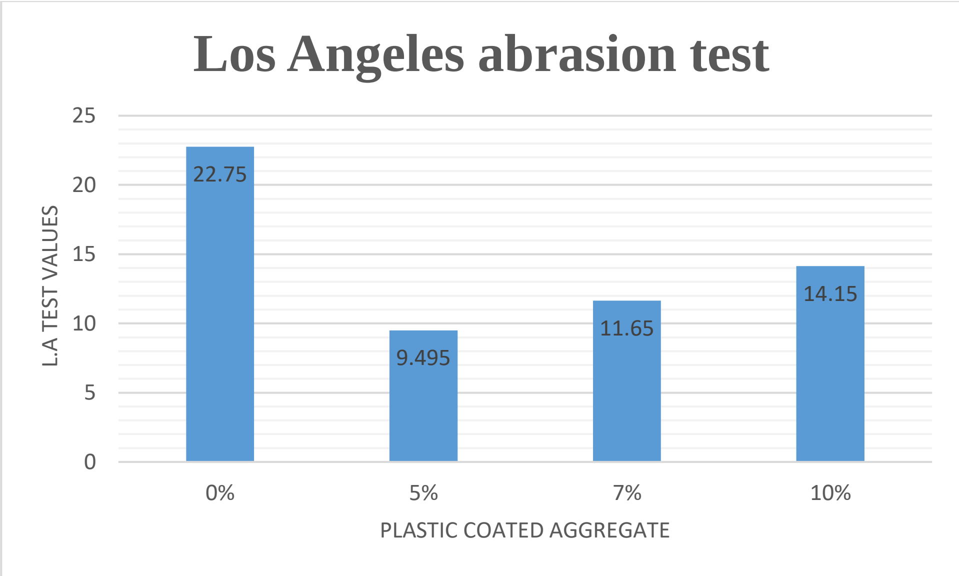

Figure 4.3. Los Angeles Abrasion test result graphical representation

4.4 Marshall Stability Test

Table 4.4. Result of Marshall Stability Test

MARSHALL STABILITY TEST					
Source (Lockhart Limestone)					
Sample No	**Normal Samples of Aggregate (Psi)**	**5% Plastic Coated Sample (Psi)**	**7% Plastic Coated Sample (Psi)**	**10% Plastic Coated Sample (Psi)**	**15% Plastic Coated Sample (Psi)**
1	2185	2835	2970	3145	3160
2	2220	2839	2975	3149	3163
3	2230	2845	2973	3153	3165
4	2175	2848	2977	3154	3163
Average	**2202.5**	**2841.75**	**2973.75**	**3150.25**	**3162.75**

According to ASTM, the specifications for Marshall stability test is >1800 psi (Nur Mustakiza Zakaria, 2018).

Marshall Stability test shows that if we apply load on a cake the point on which failure occurs. On simple aggregate the Marshall test value is 2202.5 psi, on the addition of 5% plastic with bitumen the result is 2841.75 psi,

on the addition of 7% plastic 2973.75 psi, on the addition of 10% plastic the result is 3150.5 psi and on the addition of 15% plastic, the result is 3162.75 psi.

The results show that on simple aggregate the result is less and on the addition of plastic the result becoming better and on 15% the result is not better like the previous percentages.

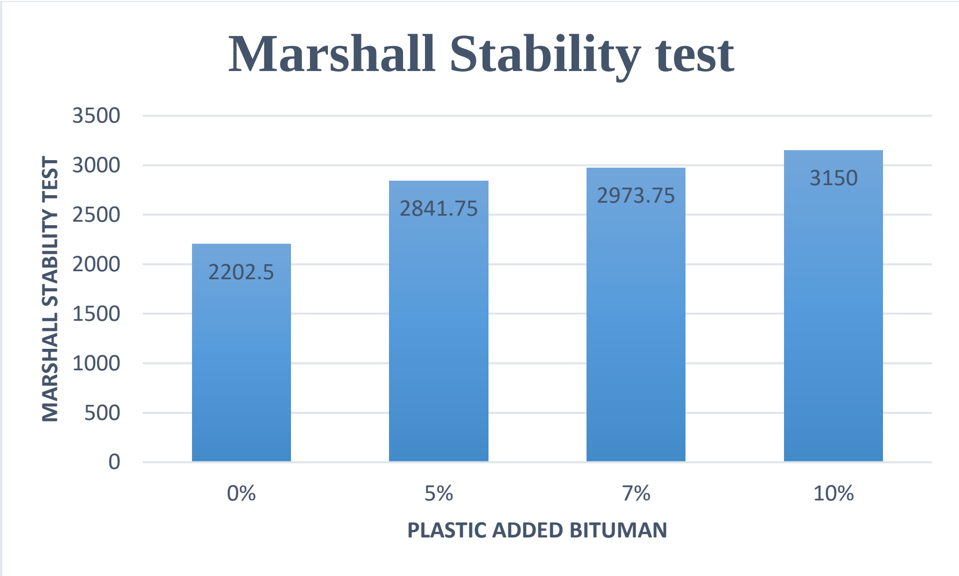

Figure 4.4. Marshall Stability Test result graphical representation

4.5 Penetration Test

Table 4.5. Result of Penetration test

PENETRATION TEST								
Sample No	**Normal Samples of Aggregate**		**5% Plastic Coated Sample**		**7% Plastic Coated Sample**		**10% Plastic Coated Sample**	
	Reading	**Mean**	**Reading**	**Mean**	**Reading**	**Mean**	**Reading**	**Mean**
1	66	65	57	57.33	53	52.66	53	53.33
	65		58		52		53	
	64		57		53		54	
2	67	66.33	56	56.33	51	52	53	54
	65		57		53		55	
	67		56		52		54	
3	67	66	57	56.33	52	52	53	53
	66		56		53		53	
	65		56		51		53	
4	65	65	57	56	52	51.66	54	53.33
	64		55		52		53	
	66		56		51		53	
Average	**65.58**		**56.50**		**52.08**		**53.41**	

According to ASTM, the specifications for penetration test is 60 to 70 for 60/70 bitumen (Nur Mustakiza Zakaria, 2018).

In the penetration test, we want to check the hardness of bitumen by penetrating a needle. So, on simple bitumen the needle penetrates, and the value is 65.58. In addition to 5% plastic, the value is 56.5, on the addition of 7% the value is 52.08 and on the addition of 10% plastic, the value is 53.41.

So, the result of simple bitumen shows that the bitumen grade is 60/70. But when we add plastic percent wise the bitumen starts becoming harder.

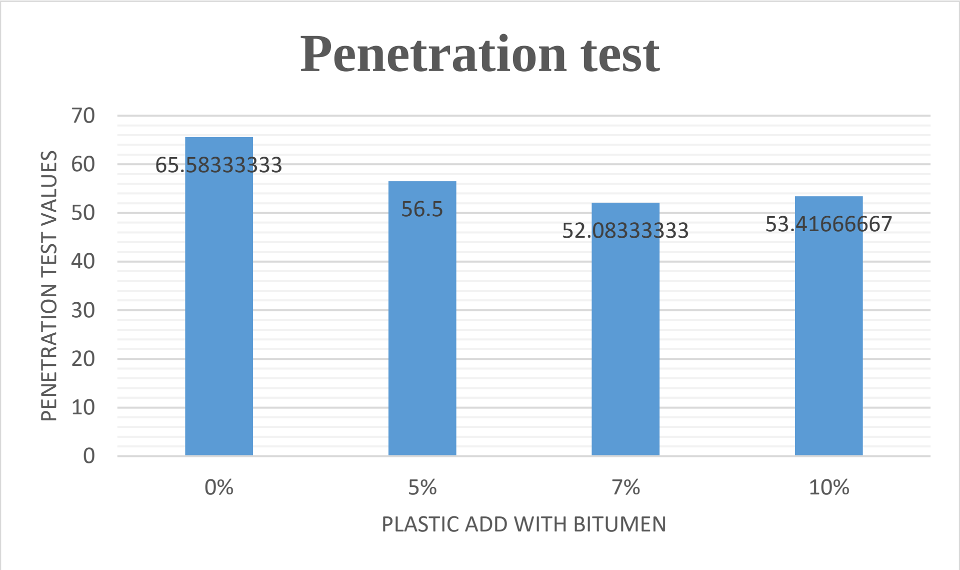

Figure 4.5. Penetration Test result graphical representation

4.6 Softening Point Test

Table 4.6. Result of Softening Point test

SOFTENING POINT TEST				
Bitumen 60/70				
Sample No	**Normal Samples of Bitumen (°C)**	**5% Plastic added Bitumen Sample (°C)**	**7% Plastic added Bitumen Sample (°C)**	**10% Plastic added Bitumen Sample (°C)**
1	45	53	57	45
2	43	54	56	49
3	43	52	57	49
4	44	53	58	48
Average	**43.75**	**53**	**57**	**48**

According to ASTM, the specification of softening point test is ranges from 49°C to 56°C (Nur Mustakiza Zakaria, 2018)

In softening point test, we observe the temperature at which the bitumen shows some sort of softening. So, on simple bitumen, the temperature is 43.75°C. In addition to 5% plastic in bitumen, the temperature is 53°C, on the addition of 7% plastic 57°C and addition of 10% plastic the result is 48°C.

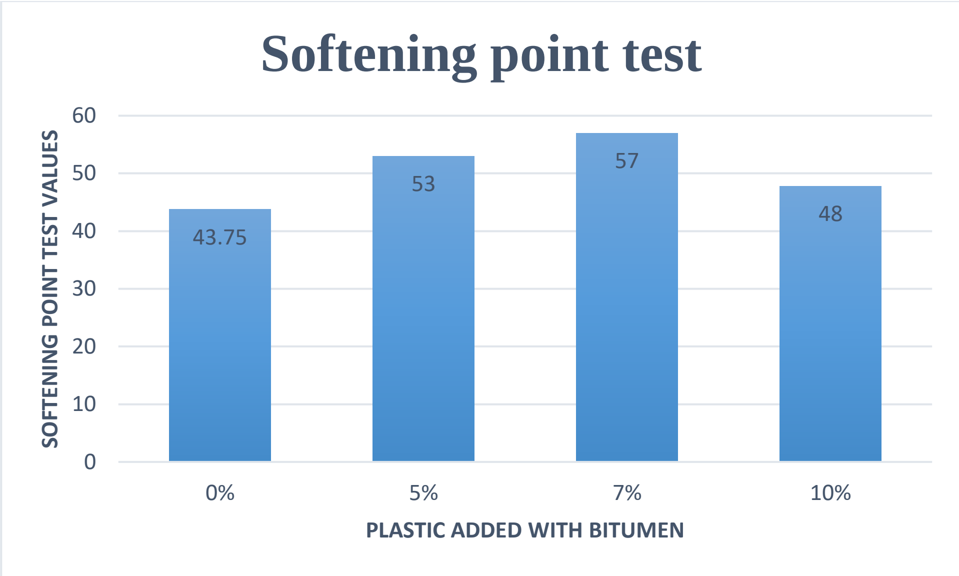

Figure 4.6. Softening Test result graphical representation

CONCLUSION

Geotechnical evaluation is important for the assessment of road aggregate suitability and performance. Geotechnical tests like aggregate crushing test, impact test, loss angles abrasion test, softening point test, penetration test and Marshal stability tests were carried out on aggregate and bitumen with adding 5%, 7% and 10 % plastic and a control test was carried out on same aggregate without plastic. Results for 5%, 7% and 10% coated plastic samples are 6.05%, 9.5% and 15.2% respectively for aggregate crushing test while non-plastic-coated aggregate show 14.5% loss. Average value of impact test of non-plastic aggregate is 22.75%, while plastic coated aggregate show 5.79%, 6.19% and 7.08% values. Los Angeles abrasion test show 9.495%, 11.65% and 14.25%. Marshal stability test show 2841.75, 2973.75, 3150.25 and 3162.75 values for 5%, 7%, 10% and 15% plastic content while aggregate with no plastic show result of 2202.5. Penetration tests showed 56.5, 52.08 and 53.41 for plastic mixed bitumen while non plastic bitumen show value of 65.5. Bitumen without plastic showed value of 43.75 while plastic coated bitumen shows 53, 57 and 48 values. All the values are within prescribed limits defined by standards like AASHTO, ASTM and NHA. This indicates Lockhart limestone as valuable aggregate for road construction. An attempt was made by coating the Lockhart limestone with 5%, 7% and 10% plastic and laboratory tests were carried out. The results of plastic-coated aggregates show considerable increase in aggregate quality performance and also meets the standard requirements. Results also indicates that the best performance can be achieved by the addition of 7% by weight of plastic

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