Comparison on the Mechanical Properties of Wearing Course Materials between JKR & LLM Specification

by

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(18001069)

Dissertation submitted in partial fulfilment

of the requirements for the

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Universiti Teknologi PETRONAS

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Certification of Approval

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Certification of Originality

This is to confirm that I am responsible for the work submitted for this project, that the original work is mine unless otherwise noted in the references and acknowledgements, and that the original work contained herein has not been undertaken or completed by unnamed sources or individuals.

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ABSTRACT

It is common knowledge that instability and unreliability are the two most common types of damages that can be sustained by a road's pavement. These are primarily the result of an increase in the number of vehicles, particularly those with high axle loads, as well as the effects of the surrounding environment, as well as mistakes made during construction and design. The design of flexible pavement takes into account the axle load limits as well as the weather conditions. The pavement's lifespan is shortened as a direct result of the severe deterioration caused by the overweight trucks. The purpose of this study is to investigate the effect that an increase in axle load has on the overall pavement life as well as the variation in pavement modulus. The purpose of this research is to compare the mechanical properties of the wearing course that was used by JKR & LLM, as well as the Marshall Stability and the conditions of the pavement material, in order to estimate the tensile strains that are occurring under the asphalt concrete (AC) layer and the compressive strains that are occurring above the subgrade surface. Due to the fact that the results showed that the tensile and compressive strains increased with increasing axle loads but decreased with increasing asphalt layer modulus, it is imperative that violating trucks have their loads reduced whenever their total weights surpass predetermined thresholds. Base thickness and subgrade resilient modulus were the primary factors that determined the equilibrium between the rutting and fatigue lives of the pavement.

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CHAPTER 1

INTRODUCTION

1.1. Background of study

The ability to travel is essential for the continued existence of human beings on this planet. Humans have developed a great deal of different modes of transportation. Paved roads are the most important and necessary mode of transportation out of all the different ways that people get from one place to another. Paved roads, or pavements in engineering parlance, can come in a wide variety of forms. When it comes to constructing pavements or paved roads, the material that is utilized most frequently is asphaltic concrete.

The components of asphaltic concrete are coarse aggregates, fine aggregates, and bitumen in varying proportions. There are many different ways in which different kinds of material can be combined to achieve the desired characteristics. The characteristics of permeability, load bearing capacity, load efficiency, and durability are included in the specification (Shahbaz, 2017). The building of new roads is a vital component in the expansion of existing infrastructure. The roads that people travel on have a direct bearing on their welfare as well as the economic activity that they participate in. The preliminary building costs associated with the development of roads are typically low and manageable financially. On the other hand, a rapid increase in traffic volumes as well as traffic volumes and traffic loads can cause a rapid decrease in the road surface and quality. Deformation can be caused by a wide variety of factors, including improper workmanship and the effects of the surrounding environment (Chai & Miura, 2002). On the long term, the cost of maintenance can become a significant burden for the parties concerned because of the conditions that have been mentioned above.

In Malaysia, there are mainly two authorities such as Jabatan Kerja Raya (JKR) and Lembaga Lebuhraya Malaysia (LLM). The roads pavement specification is controlled and being inspected by authority. The Jabatan Kerja Raya (JKR) is the most important technical department in the development of national infrastructure. JKR offers multidisciplinary expertise to ensure best practices in technical consulting, project management, and asset/facility maintenance management. LLM is supervising and carrying out the design, construction, regulation, operation, and maintenance of inter-urban highways, imposing and collecting tolls, entering contracts, and providing for related matters.

The operational performance of asphalt pavements is significantly impacted by the deformation properties, resistance to deformation, and fatigue performance of asphalt mixtures. In the process of constructing a pavement, the asphalt acts as a binder for the mineral aggregates that make up the surfacing layer. The properties of the asphalt binder that is used have the most significant impact on the mechanical properties that an asphalt mixture possesses. When it comes to the process of mixing, an asphalt binder needs to be able to remain fluid even at high temperatures (about 160 degrees Celsius), so that it can coat the aggregate in a uniform manner (Šrámek, 2018). The local climate plays a role because the binder needs to keep the prescribed amount of stiffness at the highest summer temperature to resist rutting deformations, but it also needs to remain flexible enough at low temperatures during the winter season. This is because of the local climate. The dynamic impact test and the fatigue life of a particular asphalt mixture are both utilized in the process of determining the deformation properties of the asphalt. An evaluation of the fatigue life is performed based on the degree to which various binders and mixtures experience reductions in resistance or increases in deformations.

On the other hands, pavement materials should be designed to reach a certain level of performance, and that level of performance should be maintained throughout the service life of the pavement. This will allow the pavement to provide a comfortable ride, as well as withstand the effects that arise from traffic loading and climate (Suo & Wong, 2009). Because of its superior service efficiency in delivering driving comfort, stability, durability, and water resistance, asphalt concrete is the material that is most commonly used in pavement. This is due to the fact that it is the most commonly used material. Wearing course mixtures are upper layer materials used in asphalt pavements that are directly affected by type of wearing course materials used, traffic volume and weather conditions. It is a very common to use ACWC 14 for JKR specification and ACWC 20 for LLM specification. As a result, when subjected to repeated heavy loads at high temperatures, the lack of shear strength in these mixtures increases the risk of rutting.

1.2. Problem Statement

(REMIŠOVÁ, 2013) claims that the most common type of damage that can occur to asphalt pavement is a permanent deformation that also includes cracking and potholes. It is an accumulation of a small number of deformations that take place whenever a load is applied, so it can be thought of as a cumulative effect. Heavy axle loads, particularly in conjunction with an increase in AADT, can cause stresses in the asphalt layers and lead to rutting, which is characterized by the downward and lateral movement of the mixture. Asphalt layers go through three distinct stages on their way to developing permanent deformation (rutting).

Asphalt pavements that have been damaged by moisture have been recognized as a widespread issue all over the world. It's possible that water seeping into the pavement structure could lead to layers of hot-mix asphalt failing before their time. Damage caused by moisture can typically be broken down into two distinct mechanisms, including a loss of adhesion and a loss of cohesion. Because water was able to get between the asphalt binder and the aggregate, the adhesion was lost as a result of the asphalt film being stripped away. The reduction in cohesion can be attributed to the softening of the asphalt concrete mastic. Due to the fact that the two mechanisms are interrelated, a moisture damaged pavement could be the result of the combination of both mechanisms (Nejad et al., 2012). The severity of damage caused by moisture depends on a number of different factors. The characteristics of the asphalt mixture, environmental factors, and construction practices are all included in these factors. Moisture damage has caused many pavement failures. Because moisture lowers the internal strength of the HMA mix, the stresses caused by traffic loads become significantly more severe. As a result, the HMA layer develops fatigue cracking or rutting, depending on the severity (Nejad et al., 2012). In general, the tensile strength test is what is used to determine how susceptible HMA is to fatigue and rutting, both of which are caused by moisture damage. The percentage of asphalt that is made up of air void is directly related to how long an asphalt pavement will last. This is due to the fact that the air-voids in the mixture become less permeable as they decrease in size

(Kassem et al., 2011). When there is an excessive amount of air-void content, it creates pathways through the mixture that allow harmful air and water to enter.

1.3 Aim and Objectives

The main objectives of this project are:

1. To evaluate the Marshall properties for JKR and LLM specifications
2. To evaluate the Tensile Strength of AC14 (JKR) and AC20 (LLM) wearing courses by Indirect Tensile Strength Test (ITS)

1.4 Scope and Limitations of the Research

The scope of the research involved in this project are as follows:

In Malaysia, there is always with hot weather and asphalt paved roadways can become overly smooth, but on chilly nights, they can become exceedingly fragile and break easily. Rutting is the term used to describe the permanent deformation of the pavement that can occur when heavy traffic is driven over soft asphalt pavement. Pavement cracking is a common occurrence after few years because the asphalt binder becomes more brittle during this time of year.

An asphalt mixture contains aggregate in sizes ranging from large to small. These sizes are spread throughout the mixture. There will be a greater range of sizes present in the mixture if the maximum size of the aggregate particles that can be used is increased. The distribution of grain size variation is referred to as gradation. The grading of the aggregates has an effect on a variety of cavities within the mixture and determines both the mix's workability and its stability. The process of grading aggregate can be broken down into three categories: uniform gradation, gradation, and gradation gap meetings. The aggregate is considered to be clean if it has a minimum number and type of undesirable items such as soft particles and mud that are attached to or contained within the aggregate. Aggregates gross will give poor influences on pavement performance, such as impaired bonding between the asphalt and aggregates due to the excessive clay content in the aggregate.

It is essential for there to be regular upkeep of the road infrastructure in order to preserve and improve social benefits. As a result, the significance of maintenance ought to be acknowledged by those competent authorities in charge of decision making, adequate funding, and management, so as to guarantee that maximum value is achieved. Roads are one of the most important aspects of a region's or country's infrastructure, so it is imperative that they are properly maintained in order to keep an effective and valuable road network. This means that maintaining roads that have already been constructed is just as important as building new ones. This heritage could experience significant deterioration as a result of an improper or ineffective maintenance strategy (Llopis-Castelló et al., 2020). The performance of asphalt pavements is negatively impacted significantly by permanent deformation, often known as rutting. Rutting shortens the amount of time that the pavement can be used effectively, and because it alters the way in which vehicles handle, it presents major problems for people who use the roadway. LLM and JKR roads have been hampered in the efforts to provide rutting resistant materials due to the fact that the existing methods for testing and evaluating asphalt-aggregate mixes are empirical and do not give a reliable indication of in-service performance.

1.5 Novelty of Research

The proposed of the asphalt concrete between Ac14 and Ac 20 by comparing the Marshall properties and the Mechanical properties in order to have better understanding on their durability, stability and moisture susceptibility.

CHAPTER 2

LITERATURE REVIEW

2.1. Background Study of Asphalt Concrete

Pavement materials should be designed to achieve a certain level of comfort and withstand the effects of traffic loading and climate in order to provide a comfortable ride. performance, and performance should be sustained throughout the service life Asphalt concrete is the most widely used. This is because of its superior performance in pavement service performance in terms of driving comfort, stability, and safety Water resistance and durability as asphalt concrete ages The course is the first layer of a pavement structure. The material should be able to withstand direct stresses. Traffic loading can be achieved without causing premature cracking (Suo & Wong, 2009)

2.2. Flexible Pavement in Malaysia

Flexible and stiff pavement structures are common. Flexible pavements deform in layers and are comprised of asphalt with no binding elements (Chegenizadeh et al., 2016). Each layer of a flexible pavement helps spread out stresses. Flexible pavements have no strength. Granules operate as stress contact points between layers. Contact pressure equals the surface's maximal compressive stress. Lower layers are less stressed because loads are spread out. The top layer of flexible pavement is the most compression-resistant. Materials that can't handle compression loads directly, like industrial waste, could be employed in lower layers. 95% of the world's roads are flexible. This construction has four layers: subgrade, subbase, base, and surface (Gautam et al., 2018).

Malaysia builds sustainable roadways to conserve natural resources. Using natural aggregates to build and maintain many pavements worldwide goes against this purpose. This irresponsibility causes climate change, ignorance of non-renewable materials, and greenhouse gas emissions. All pavements must fulfil sustainability criteria, however Malaysian roadways predominantly use flexible pavement, therefore emphasis there. Asphalt covers flexible pavements. Mostly tiny rocks and bituminous paste. 95% of the world's roads are flexible. Subgrade, subbase, base, and surface are its four strata (Gautam et al., 2018). Sub-grade is the natural soil used as a basis. Existing subgrade is often unstable or expansive, therefore a minor change in moisture can produce a considerable volume shift in a short time. Subgrade is amended using additives. This sub-grade is called "subbase." The base course is a load-bearing layer comprised of high-quality, varying-sized aggregates. The surface course of aggregates, fines, filler, and binder (Gautam et al., 2018). Because this layer is in direct contact with the load of the traffic, employing the use of a material of superior quality is an absolute requirement.

2.3. Hot Mix Asphalt (HMA)

Hot mix asphalt, or HMA, is the most common paving material worldwide. Mostly mineral aggregates and asphalt cement binder. It's a mixture of heated, dried, and hot asphalt-bound mineral aggregates. It's called hot mix asphalt. Mineral aggregate coupled with asphalt binder provides strength and abrasion resistance (Mamat, 2008). HMA's behaviour depends on its elements and how they interact inside the system. Hot mix asphalt (HMA) is a composite comprised of varying-sized aggregate particles, an asphalt binder, and air gaps. Extremely abrasive, low-workability combinations can make it difficult to produce smooth pavements, and even when compacted, they may have performance issues because to excessive voids. Uncompacted material increases permeability difficulties and oxidative ageing of the binder, which reduces pavement life (Gudimettla et al., 2003). Mixture design consists of volumetric design and empirical mechanical testing to verify the design. The design process may also set additional requirements for the combination to meet the overall standard. In such instances, a minimum percentage of crushed aggregate, a maximum amount of rounded sand, and aggregate gradation guidelines may be imposed (Mamat, 2008).

2.4. Fatigue Failure on Asphalt Pavement

Fatigue is the biggest problem with flexible pavements. (Figure 2-1) Symptoms include: It's linked to recurrent traffic loading and pavement depth, appearing as cracking (alligator cracking). Fatigue causes microcracks that grow into macrocracks (Witczak & El-Basyouny, 2004). Shear and tensile strains in the road pavement produce cracking. Temperature and air spaces affect the pavement's fatigue life. Properties include binder kind and amount. In addition, aggregate gradation affects asphalt mixture fatigue resistance. This was more crucial than asphalt content (Taher et al., 2011).

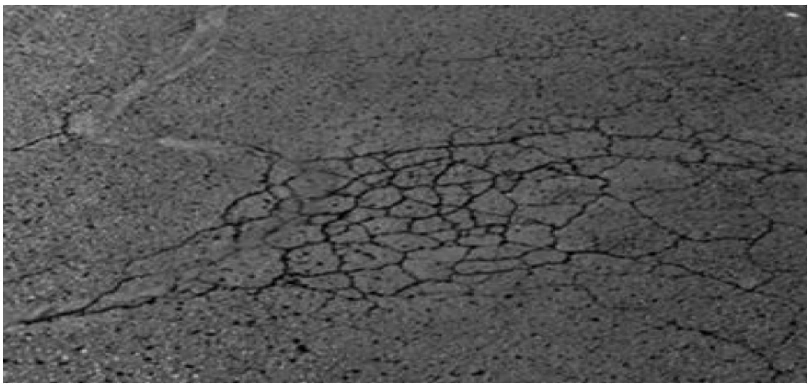


Figure 2.1: Alligator Cracks

The road construction business has advanced thanks to new technologies, yet the quality of existing roads varies. As the road's surface, asphalt concrete pavement endures repetitive vehicle loads and seasonal variations. Cyclic loading shifts a material's stresses and strains, reducing its strength. Cyclic loading can fatigue pavement (Sun et al., 2018). Interlayer bonding between bituminous layers affects pavement performance. Interlayer bonding is necessary for transferring normal and shear stresses caused by traffic loading throughout the bituminous layers, which gives the pavement structure the best load-bearing capability. Inadequate bonding between bituminous layers may produce low performance, leading to slippage cracking, top-down cracking, and permanent deformations, especially in locations where vehicles often accelerate, brake, or turn suddenly. Interlayer bonding depends on many parameters, including the materials utilised (Ragni et al., 2020). Indirect Tensile Fatigue Test was used to evaluate hot-mix asphalt (HMA) combinations' fatigue resistance.

2.5. Rutting in Pavement

Rutting failure is one of the most visible road faults. This type of collapse is more common when traffic is stopped or moving slowly, which increases pavement loading. The load causes the failure, which eventually leads to cracking and potholing in the mixture, which is evaluated using Marshall Stability (Chilukwa & Lungu, 2019).

Rutting in pavement is created by longitudinal surface depression and transverse displacement. This reduces a flexible pavement's serviceability and safety. Ruts can be stable or consolidated. Rusting can result from permanent volume reduction (consolidation/traffic densification) or continual volume mobility (plastic deformation/shear). Both are "permanent" processes. Elastic qualities don't cause permanent deformation, thus they may be modelled using Poisson's ratio and modulus of elasticity. Plasticity causes persistent distortion under repeated loading. Deformation accumulates. Several factors affect rut formation. Temperature, asphalt/bitumen mixture parameters, and building quality are model constants. Vehicle speed/time and contact pressure directly represent creep rate. To prevent rutting, pay attention to materials' shear resistance, especially bituminous ones. Shear resistance of bituminous layers is left to mixture designers, even if the primary focus of pavement structural design techniques has been preserving the subgrade from excessive vertical strain. The Marshall Stability test measures bituminous mixture shear resistance (Nagabhushana et al., 2013).

Rutting failure shortens the road's lifespan and endangers travelers' safety. When driving over rutted pavement, steering is harder and driving comfort is reduced. Rainwater in a rutted tyre path can cause hydroplaning and spray. This reduces visibility. Rutting is such a problem on today's roadways that it's now a design criterion for asphalt pavements. Permanently deformed asphalt pavements can be divided into three stages based on material, load, and environmental factors. Figure shows. In the basic stage, rutting is significant and plastic deformation, which causes volumetric change, decreases gradually. The secondary stage has a modest rutting rate and steady rutting change, which is coupled with volumetric changes. During this stage, shear deformations grow. In the tertiary stage, rutting is associated with plastic (shear) deformations and occurs without volume change. (Chilukwa & Lungu, 2019). In order to study the rutting performance of materials in asphalt pavement used the Repeated Load Axial Test to evaluate the Rutting resistance for hot-mix asphalt (HMA) mixtures.

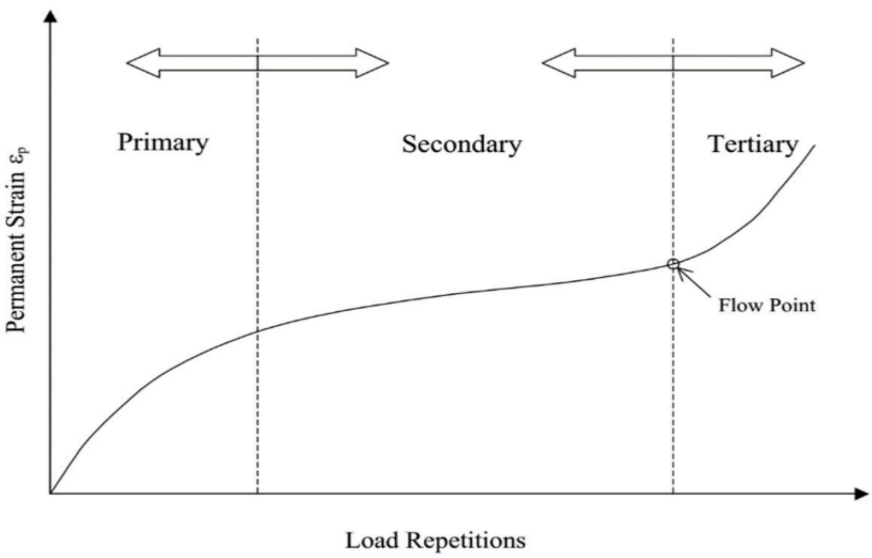


Figure 2.2: Repeated load permanent

2.6. Stiffness of Pavement

After evenly distributing the aggregate, a thick coating of asphalt is applied. It makes asphalt. Formulating asphalt mixture requires a lot of characteristics to provide strength and durability. A material's stress-and-strain diagram shows its stiffness, which is one of the asphalt mixture's characteristics for strength and durability. The elastic modulus is used to estimate the stiffness of a material. The elastic modulus of a material measures how rigid it is; the less its shape changes when subjected to a force, the greater its modulus. So, the higher the stiffness modulus, the smaller the elastic strain and the more rigid the object (Lubis et al., 2018). Asphalt pavement rigidity modulus affects performance. If the stiffness modulus lowers, aged asphalt pavement will crack when loaded heavily. Age causes this. Asphalt concrete's high stiffness modulus makes constructions more rigid and bending-resistant.

The stiffness of the pavement, which is dictated by recurrent traffic stress and pavement thickness, is an important design component. Asphalt pavement flexural stiffness is related to HMA qualities such rutting, resilient modulus, and fatigue life. In addition, asphalt pavement thickness affects flexural rigidity (Xiao & Amirkhanian, 2009). When asphalt is subjected to cyclic load or stress, its response in tension and compression consists of three major strain components related to stiffness. Elastic, viscoelastic, and plastic strain components. Perfectly elastic materials can be loaded indefinitely before their flexural stiffness changes (Khattak & Baladi, 2001).

2.7. Wearing Course Used by JKR and LLM Specifications

In Malaysia, ACWC 20 aggregate is commonly used in highway construction. The Asphaltic Concrete Wearing Course (ACWC) 20 is a mixture that has small maximum particle sizes and is continuously graded. The mineral aggregate, filler, and bituminous binder that it contains come together to form an interlocking structure, which contributes to the design mix's overall strength and performance (Mohd Kabri, 2008). According to current practice, ACW20 is the preferred design mix for Malaysian expressways.

In past years, the government of Malaysia has shown an increased interest in exploring novel approaches to the construction of pavement, conducting research and development for roads, bridges, and highways, and making use of new pavement and surfacing pavement. These initiatives are part of a broader push to modernize Malaysia's infrastructure. The majority of the country's roads were constructed with asphalt concrete wearing course 14, abbreviated as ACWC 14. The work component of the construction of the road is still in accordance with the Arahan Teknik Jalan established by Jabatan Kerja Raya Malaysia (JKR) and the standard specification for works established by JKR Malaysia. The Arahan Teknik Jalan has decided to adopt the standards that have been established by the American Association of State Highway and Transport Officials (AASHTO) in order to specify their standards in accordance with the availability of material and the unbound condition that was encountered during the construction of pavement (Rahim, 2009).

2.8 Marshall Stability and Flows for JKR and LLM Specification

For LLM, The Marshall Stability and Flow tests were utilized so that the compacted HMA samples could be evaluated regarding their capacity to withstand load and deformation. The Marshall Stability index is a measure of the maximum load that the samples are capable of bearing. The flow value is the deformation that the test specimen goes through while being loaded up to its maximum load and this deformation is measured before and after the loading process (Shah & Abdullah, 2010). Prior to the testing, the samples that were prepared with the ideal amount of asphalt were heated in a water bath maintained at a temperature of sixty degrees Celsius for thirty to forty minutes. The item is then transferred to a Marshall testing machine, where it remains until it is subjected to a load that is exerted by two semicircular testing heads measuring 100 mm in diameter and moving at a compressive rate of 50 mm per minute. When the sample was loaded to its maximum capacity, measurements were taken of both its stability (in kilograms) and its flow (in millimeters of deformation) (Shah & Abdullah, 2010).

Table 2.1: Marshall Mix Design Properties For Different Aggregate Shape(LLM)

Mix Properties	**Aggregate Shape**		
	Angular	***Elongated***	***Flaky***
Stability (kg)	554	447	343
Flow (0.25 mm)	8.83	9.50	9.70
OAC (%)	5.04	5.18	5.32
VMA (%)	15.4	15.5	15.8

For JKR, At a loading rate of 50.8 millimeters per minute, the Marshall Stability test determines the maximum load that can be supported by the bituminous material. The amount of the test load that must be carried is increased until it reaches its maximum. After that point, the loading process is terminated as soon as the load begins to slowly decrease, and the maximum load, as determined by Marshall Stability, is recorded. During the loading test, a dial gauge is attached so that the plastic flow of the specimen can be measured in response to the load that is being applied. When the maximum load is applied, the vertical deformation corresponding to the flow value is determined. The resistance of bituminous materials to shearing stresses, rutting stresses, rutting distortion, and displacement distortion is referred to as Marshall Stability. Internal friction and cohesion are the primary contributors to the stability of the system. The binding force of a binder material is referred to as cohesion, whereas the interlocking and frictional resistance of aggregates is referred to as internal friction. Because bituminous pavement is occasionally subjected to severe traffic loads, it is essential to use bituminous material that possesses both good stability and flow (Oluwasola et al., 2015).

Table 2.2: Marshall Mix Design Properties For JKR ACW 14

Property	Mix 1
	80–100
O.B.C (%)	5.04
Air void (%)	4.5
Bulk specific gravity	2.325
Marshall stability (kN)	13.70
Flow (mm)	3.07
M_Q (kN/mm)	4.463
VMA	15.6

CHAPTER 3

METHODOLOGY

3.1. Introduction

An overall research methodology that consists of a number of activities that are based on the targeted objectives of the project has been described. This has been done in order to make certain that the project can be finished in a timely manner. The flowchart that represents the overall research methodology is shown in figure.

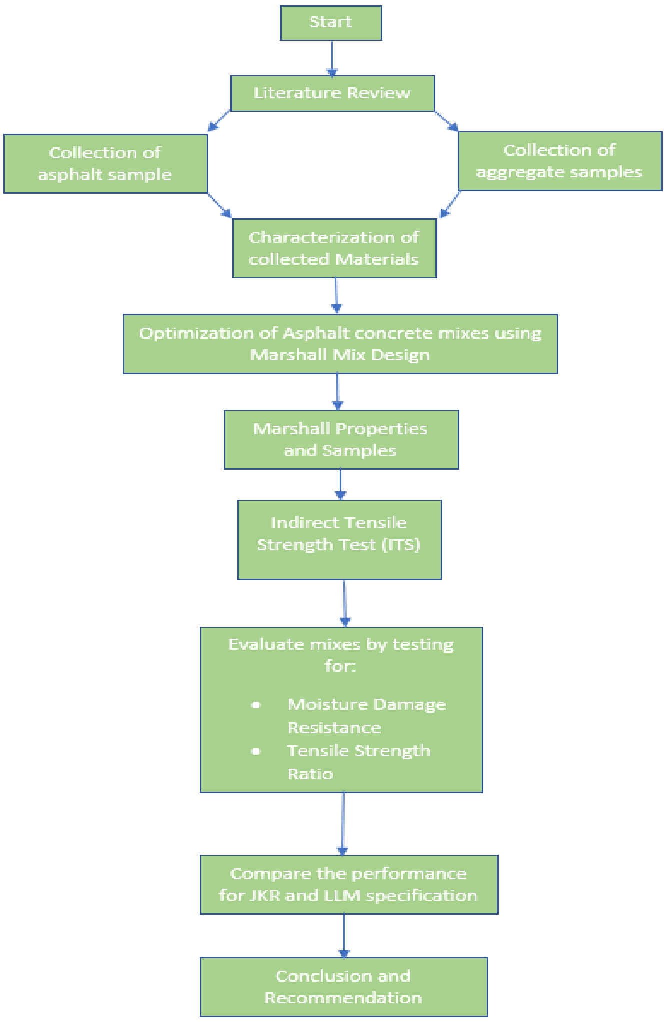


Figure 3.1: Preparation of Flow Chart

Table 3.1: Summary of Tests

Test	Purpose
Marshall Stability and Flows Test (ATSM D6927-15)	Marshall stability and flow values along with density; air voids in the total mix
Indirect Tensile Strength Test (AASHTO Designation: T 283-21)	Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

3.2. Materials:

For LLM, in this research made use of granite aggregates obtained from a quarry in Cheras, which is located in Malaysia. The aggregate grading that was utilized was done so in accordance with the grading that was specified in the Standard Specifications for Road Works published by the Public Works Department of Malaysia, which can be found in Table 2.5 .Within the grading envelope, there were three distinct grading lines that were utilized (Figure 1): the middle (which was located halfway between the upper and lower grading lines), the middle –25 percent (which was located between the middle and lower grading lines), and the middle +25 percent (between mid and upper grading lines) (Arshad et al., 2018). Bitumen with a penetration of between 60 and 70 and between 80 and 100 was used in both of the asphaltic concrete mixes (Arshad et al., 2018). In order to prepare the samples for testing, they were conditioned for twenty-four hours at a temperature of twenty-five degrees Celsius in an environmental chamber.

Table 3.2: Grading Envelop for ACWC 20

Sieve Size (mm) BS Sieve	ACW 20 Wearing Course (% passing by weight)	ACB 28 Binder Course (% passing by weight)
37.5	-	100
28.0	100	80–100
20.0	76- 100	72–93
14.0	64–89	58–82
10.0	56–81	50–75
5.0	46–71	36–58
3.35	32–58	30–52
1.18	20–42	18–38
0.425	12–28	11–25
0.150	6–16	5–14
0.075	4–8	3–8

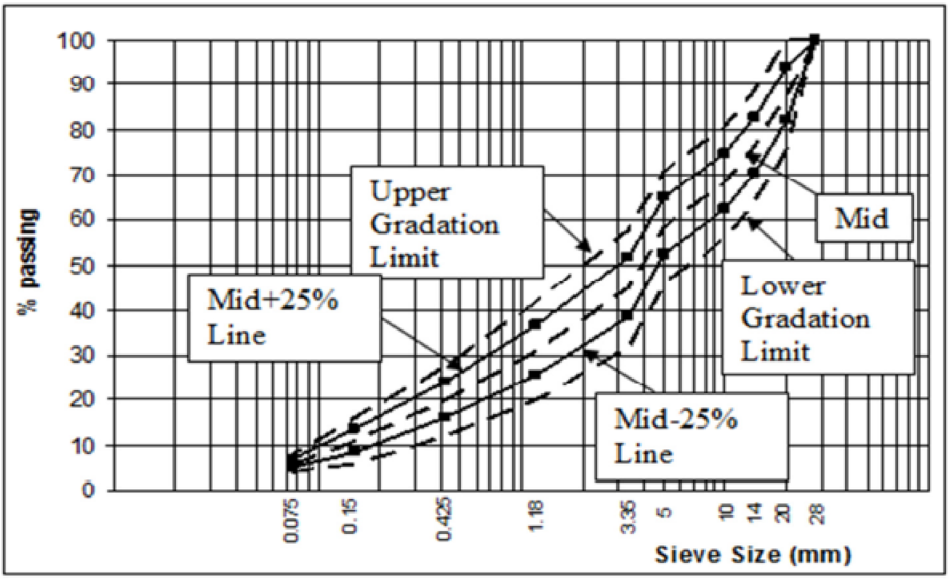


Figure 3.2: Grading lines and envelope for ACW 20 mix

For JKR, Granite stone obtained from the Sunway Quarry in Kampar, Ipoh, and Perak was the type of aggregate that was decided to be used for the research activities. The mineral aggregate was allowed to dry in the oven at a temperature of 120 degrees Celsius for a period of 24 hours (Yaro et al., 2021). According to the predefined gradation of the Malaysian Ministry of Public Works (PWD), the aggregate gradation ACW(AC14) was chosen for a wearing course intended for heavy traffic. The aggregate that was utilized in the research was subjected to sieve analyses, and the results of those analyses are presented in Table 2.6 below.

Table 3.3: Grading Envelop for ACWC 14

Sieve size (mm)	Specified percent passing range	Percent passing used (%)
20	100- 100	100
14	90-100	95
10	76-86	81
5	50-62	56
3.35	40-54	47
1.18	18-34	26
0.425	12-24	18
0.15	14-16	10
0.075	4-8	5
Pan		5

3.3. Marshall Stability Test

The weight of the dry blended aggregates was determined to be 1200 g for each specimen. The temperature of the aggregate mixture was brought up to 160 degrees Celsius. After heating the aggregate, it was transferred to a pan where it was thoroughly combined. After creating a crater in the aggregate, the 60/70 penetration grade bitumen was added while it was heated to 160 degrees Celsius. After a thorough mixing, the bitumen and the aggregates were combined. This continued until the aggregates were sufficiently coated. A temperature of 160 degrees Celsius was applied to both the thoroughly cleaned specimen mould assembly as well as the compaction hammer.

After placing a piece of filter paper at the bottom of the mould, the mixture was then added to the mould. Finally, the perimeter of the mould was scraped with a heated spatula to smooth it out. After removing the collar, the surface of the mixture was brought to a slightly more rounded shape by using a trowel to smooth it out. The temperature of the mixture was kept at 150 degrees Celsius right up until the moment before it was compacted. After the collar had been replaced, the mould assembly was positioned on the compaction pedestal inside the mould holder, and then 75 blows were delivered to the top of the specimen. Following the removal of the baseplate and the collar, the sample was turned upside down, and the mould was then reassembled. Additionally, 75 blows were delivered to the inverted face. Following the completion of the compaction process, the base plate was taken off, and the mould that contained the specimen was submerged in chilly water for a period of two minutes. The sample was extracted from the mould utilizing a sample extractor in conjunction with an appropriate jack and frame arrangement. After allowing the specimen to cool at room temperature, it was placed on a surface that was both smooth and flat.

In order to get an accurate reading of the specimen's density, it was weighed in both air and sterile water at room temperature. The difference in gramme weight between the two weights was used as the basis for calculating the volume.

The specimen was immersed in a water bath for 20 to 40 minutes in order to bring it up to the test temperature before the stability and flow determinations were made. The inside surfaces of the test heads as well as the guide rods received a comprehensive cleaning. It was necessary to lubricate the guide rod in order to ensure that the upper test head could slide easily over them. The specimen that had been sitting in the water bath was transferred to the lower section of the breaking head. Following this step, the upper portion of the breaking head was mounted onto the specimen, and the entire assembly was then positioned appropriately on the testing apparatus. While the load was being applied, the flowmeter was maneuvered into position so that it would rest atop the guide rods, and the sleeve was pressed firmly up against the most elevated portion of the breaking head. Before beginning the test, the flow meter was calibrated so that it would read zero. The load was gradually increased on the specimen at a rate of fifty millimetres per minute until the maximum load was reached, at which point the load started to gradually decrease. After noting down the maximum load, the flowmeter was removed from its perch atop the guide rod as soon as it became apparent that the load was beginning to ease off.

The value of the flow was read and written down. In the course of the test, the amount of time that passed between the removal of the sample from the water bath and the determination of the maximum load did not go beyond thirty seconds. Figure 3-2 depicts the Marshall stability machine with the specimen already in place.

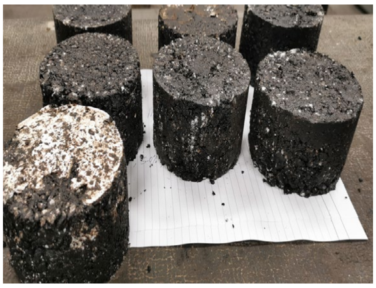
Figure 3.3: Marshall Stability Flow Test Machine

3.4. Indirect Tensile Strength Test

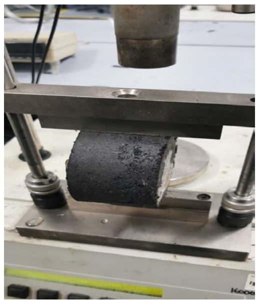
The change in indirect tensile strength is evaluated using six samples: three dry samples and three water-exposed samples. During the indirect tensile strength test, the sample is secured between two load stripes and radially loaded at a rate of 50mm/min. Determine the maximum force at fracture. For each set of mix conditions, such as asphalt binder untreated, asphalt binder treated with anti-stripping agent, and aggregate treated with lime, test specimens are constructed. Each specimen collection is subdivided into subsets. One subset is evaluated for indirect tensile strength under dry conditions. Before testing for indirect tensile strength, the other subset is exposed to vacuum saturation and a freeze cycle, followed by a warm-water soaking cycle. From the two subsets of test data, dry and conditioned, numerical indices of retained indirect tensile strength qualities are computed.

(a)

(b)



(c)



(d)

FIGURE 3.*4*: Sample preparation (a) Sieving (b) Heating (c) Sample for AC14 and AC20 (d) IDS Testing

CHAPTER 4

RESULT AND DISCUSSION

4.1. Introduction

Figure 4.1: 60/70 Pen Bitumen

This chapter presents the analysis from the sample of mixing with bitumen graded of 60/70 in the range of 4% to 6% (Qasrawi & Asi, 2016). The bitumen graded of 60/70 are popularly used in Malaysia for JKR and LLM. The discussion of the experimental results conducted to compare the Marshall stability and its Mechanical properties specification of ACWC 14 and ACWC 20 (Mohamed & Boulbibane, 2011).

4.2. Marshall Properties

Table 4.1: Summary of ACWC 14

Summary of ACWC 14 (Avg Results)				
Bitumen Content %	Average SG_{bulk}	Average VIM	Average Stability (kN)	Average Flows (mm)
4	2.39	6.14	12.06	2.96
4.5	2.37	6.31	11.46	3.01
5	2.42	3.42	15.74	3.15
5.5	2.41	3.42	14.51	4.05
6	2.38	3.59	11.91	4.06

Table 4.2: Summary of ACWC 20

Summary of ACWC 20 (Avg Results)				
Bitumen Content %	Average SG_{bulk}	Average VIM	Average Stability (kN)	Average Flows (mm)
4.0	2.28	10.63	20.98	3.11
4.5	2.28	14.51	15.01	3.65
5.0	2.28	14.63	13.59	3.71
5.5	2.49	10.49	10.11	4.26
6.0	2.40	10.17	9.00	2.99

When it comes to the quality of the bitumen that is being laid down and compacted, one of the most important control parameters to consider is the air void content of the bituminous materials (Harvey & Tsai, 1996). It is possible for air and water to penetrate the structure if the percentage of air voids is too high (Fernandes et al., 2017). In addition to this, it quickens the rate at which binders become more rigid, which leads to the premature embrittlement of pavements. In addition to this, having a void content that is too high will cause differential compaction, which will lead to the formation of ruts and grooves along the wheel track when traffic loads are applied to the surface (Sinanmis & Woods, 2022).

However, a certain amount of air void ought to be preserved in order to prevent the occurrence of instability during the process of compaction and to provide space for the flow of bitumen during long-term consolidation when subjected to traffic loads (Kandhal et al., 1998). In the absence of an adequate number of air voids in the design, bleeding and a loss of stability may occur, and the pavement may deform easily when subjected to extreme loads. Air voids are designed to make room for the expansion of the binder during the summer, as well as for compaction (Kandhal et al., 1998).

`The Marshall stability test determines a bituminous material's ability to withstand its maximum load at a loading rate of 50.8 millimetres per minute (Moghadas Nejad et al., 2014). The amount of the test load that must be carried is increased until it reaches its maximum. After that point, the loading process is finished and the maximum load, also known as the Marshall stability, is recorded as soon as the load begins to gradually decrease. During the loading test, a dial gauge is attached so that the plastic flow of the specimen can be measured in response to the load that is being applied. When the maximum load is applied, the vertical deformation corresponding to the flow value is determined.

The flow value is used to indicate that the vertical deformation of the sample is 0.25 mm (measured from the beginning of the loading to the point at which the sample's stability begins to decrease). Low flow values may indicate a mix with higher-than-normal voids and insufficient asphalt for durability, as well as one that may experience premature cracking due to mixture brittleness during the life of the pavement. High flow values indicate a plastic mix that will experience permanent deformation under traffic (Soliman & Shalaby, 2015). On the other hand, low flow values indicate a plastic mix that will experience permanent deformation under traffic.

4.3. Marshall Stability and Flows

The correlations between Marshall stability, Flow values, Air void in the sample, and bulk density were utilised to calculate the best amount of bitumen content for bituminous mixtures using standard filler and varying amounts of bitumen (Kok & Yilmaz, 2009).

The curves were totally drowned within Table 4's data. From figure 4.2 to figure 4.2.3, curves are displayed. The ideal bitumen concentration is 5.56 percent, according to the calculation performed using the prior value. When the stability, flow, %Va, %VMA, and %VFB values for optimal bitumen content are utilised, the Marshall Mix Design Criteria are satisfied.

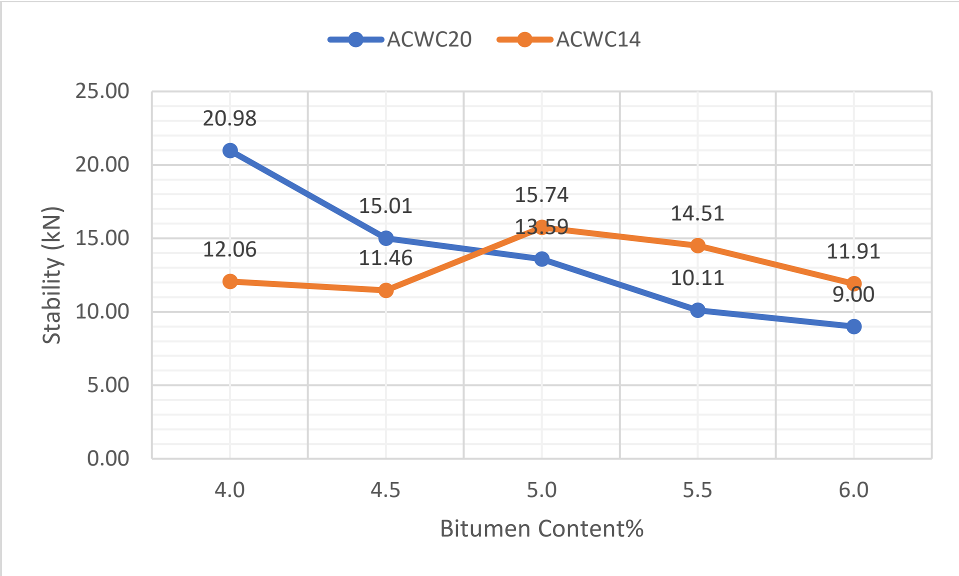


Figure 4.2 Stability vs BC

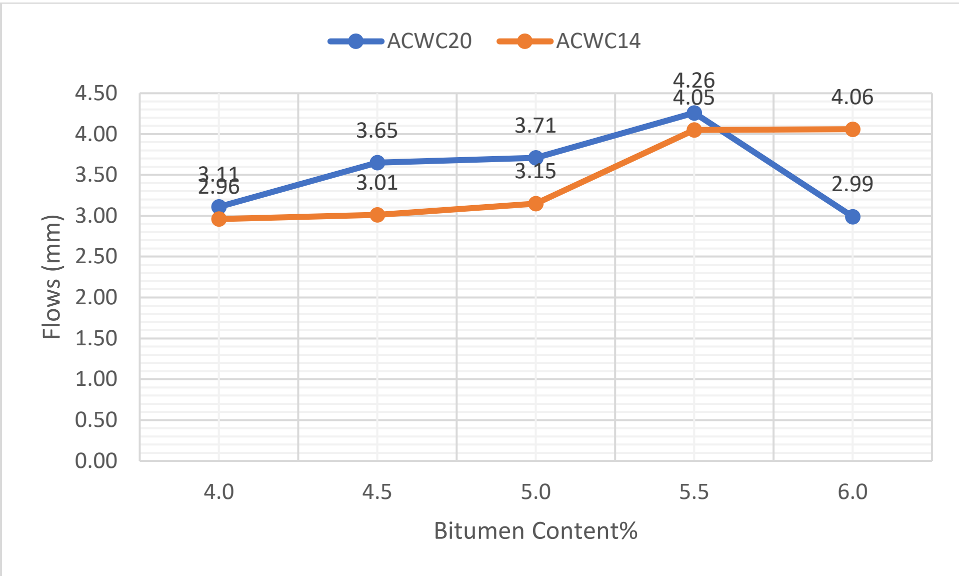


Figure 4.2.1 Flows vs BC

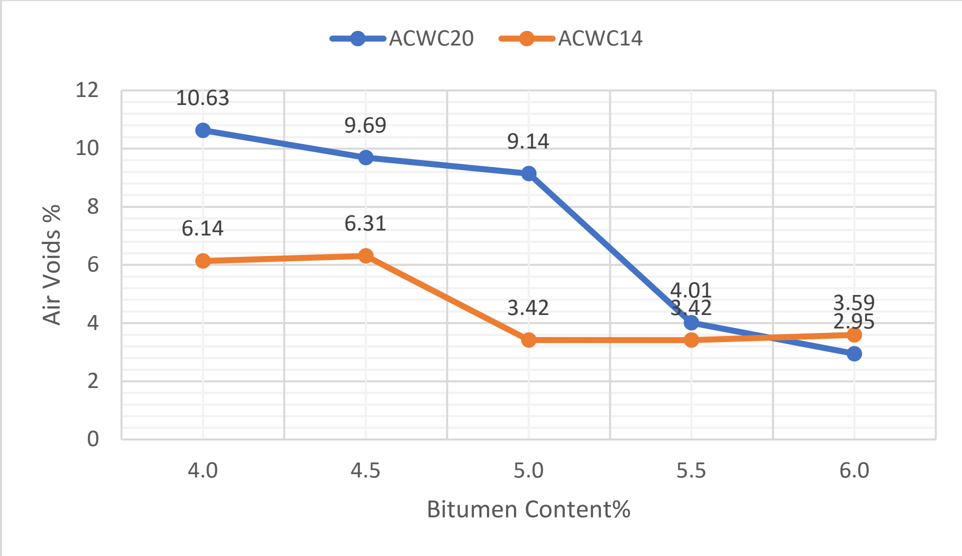


Figure 4.2.2 Air voids vs BC

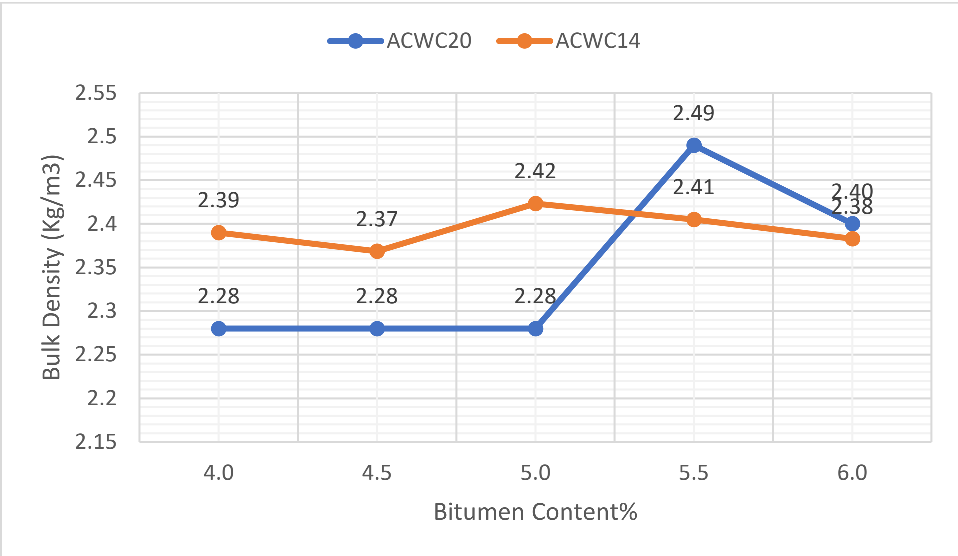


Figure 4.2.3 Bulk Density vs BC

The outcomes of the stability tests are presented in Figure 4.2. The findings indicate that the stability improves with increasing bitumen content up to the point where it reaches its optimal level, after which it begins to deteriorate again (Chen et al., 2009). It was discovered that the bitumen content of 4.0% for AC20 and AC14 were the ideal level. It was discovered from the JKR and LLM's gradation that the mixture containing different size of aggregate and filler had a degree of stability that was marginally superior to the mixture. At an optimal bitumen content of 4.0%, the mixtures had stability values of 20.98 kN and 12.06 kN, respectively. It can be seen that the stability values for both mixtures met the requirement that they must be at least 3.5 kN in order to pass the requirement according with JKR and LLM standards. According to the findings, the asphalt mixture for ACWC14 are having greater stability than ACWC20. The improved adhesion between the aggregate and the bitumen can be credited with the increase in stability that was observed. To verify this, however, additional tests such as the indirect tensile strength test or other similar tests will be conducted in subsequent research.

Figure 4.2.1 illustrates the relationship between the flow values of the two asphalt mixtures and the amount of bitumen present in each. It is clear from looking at the results that the flow are increasing as the amount of bitumen in the mixture increases. The flow value of the mixture were 4.26 millimeters for ACWC20 and 4.05 millimeters for ACWC14 when the optimal binder content was 5.5%. From the observation, ACWC 20 had higher flows compared to ACWC14. It is necessary to point out that the flow value does not accurately reflect the asphalt mixtures' resistance to permanent deformation, but this point needs to be made clear (Mirzahosseini et al., 2011). In subsequent research, there will be an increase in the number of tests, such as the repeated load axial test (RLAT) and the wheel tracking test, among others, that can more accurately evaluate the asphalt mixtures' resistance to permanent deformation (Susanto et al., 2022).

The percentage of voids in the total mix is plotted against the amount of bitumen in Figure 4.2.2. When compared side by side, the asphalt mixture has significantly fewer voids when the binder content is optimized. Although ACWC14 has a higher air voids than ACWC20, the lower voids in the mixture may be attributable to the improved bonding achieved as a result of asphalt surface modification and the stiffening effect. This may be the case because size of aggregate has a higher stiffening effect. In general, it is possible to see that the voids filled with bitumen increase with increasing bitumen content for both mixtures. This is something that can be observed. As can be seen in Figure 4.2.2, the bulk density increases as the amount of bitumen in the mixture does as well.

4.4. Optimum Bitumen Content

4.4.1. OBC for ACWC 14

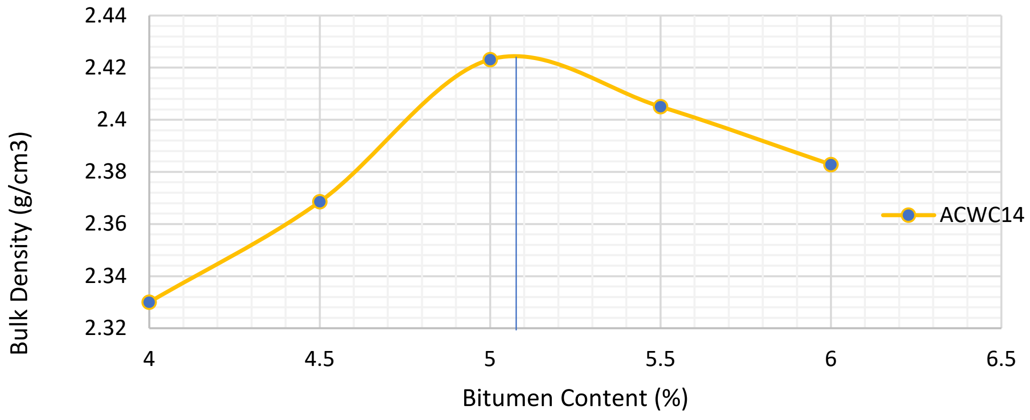


Figure 4.3 Bulk Density vs BC (AC14)

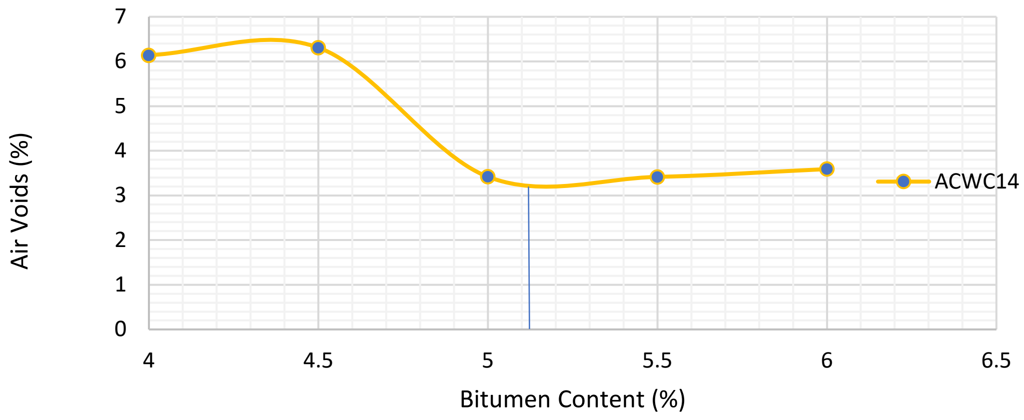


Figure 4.3.1 Air voids vs BC (AC14)

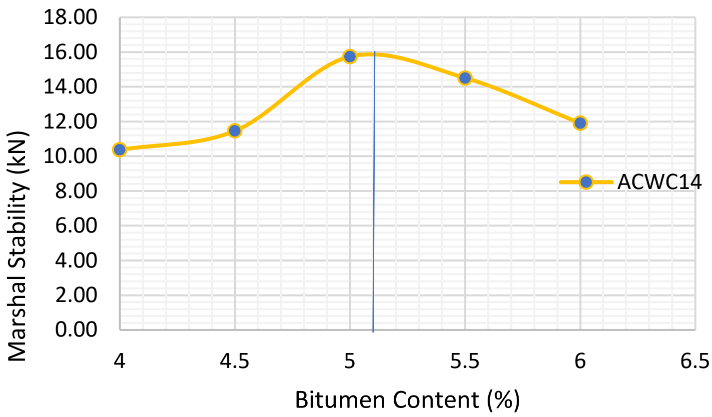


Figure 4.3.2 Marshall Stability vs BC (AC14)

The optimum bitumen content for ACWC 14 is 5.10%. This OBC are determined from Bulk Density, Air Voids, and Marshall Stability. The highest point in graphs will be taken for Bulk Density and Marshall Stability. The lowest point in the graphs will be taken for air voids.

4.4.2. OBC for ACWC 20

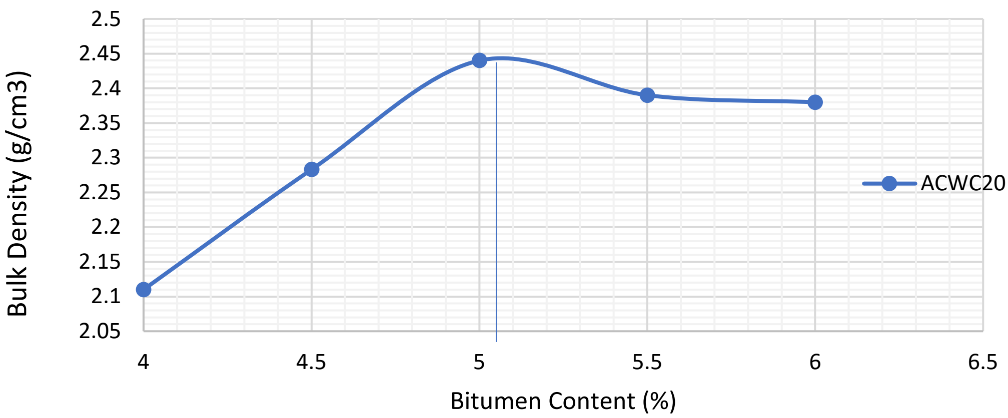


Figure 4.3.3 Bulk Density vs BC (AC20)

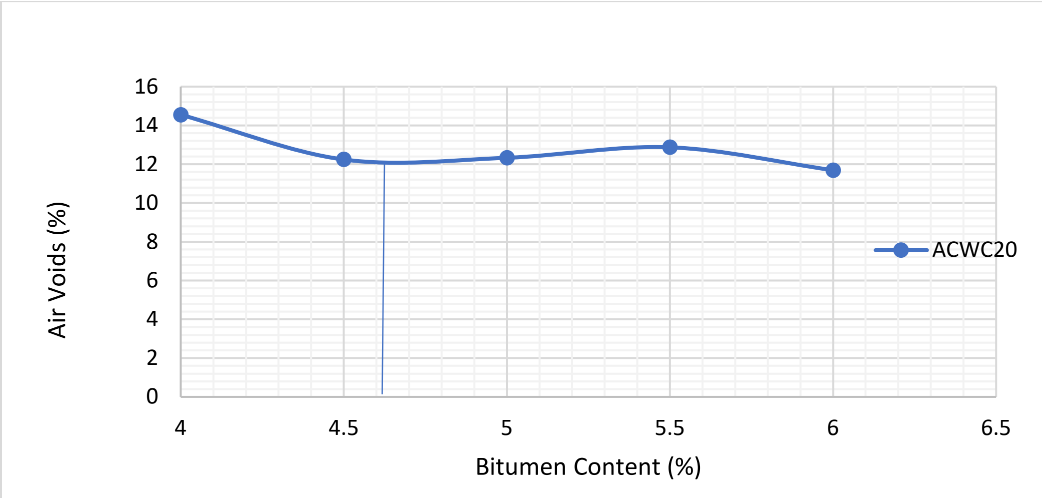


Figure 4.3.4 Air Voids vs BC (AC20)

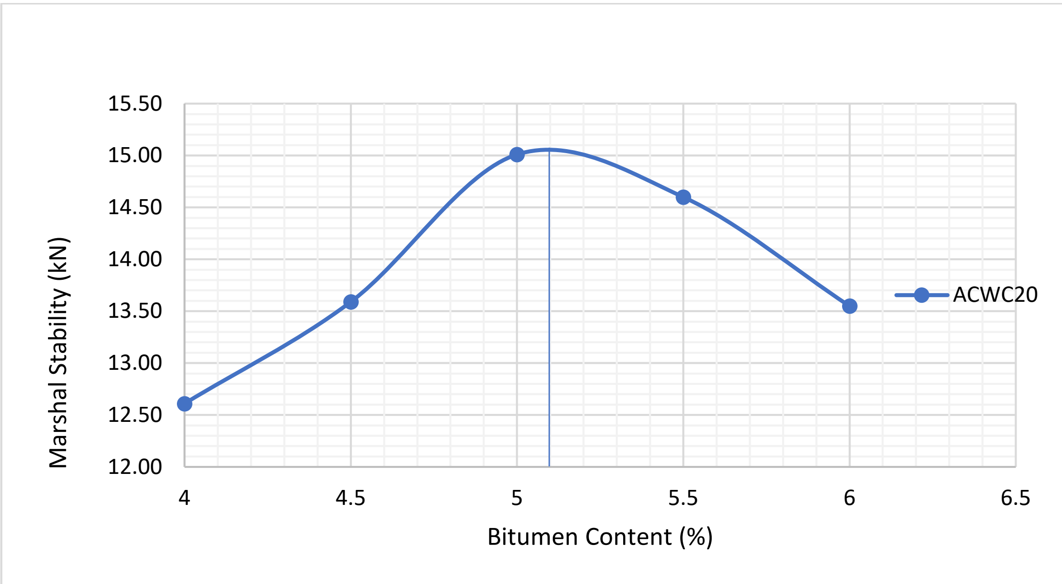


Figure 4.3.5 Marshall Stability vs BC (AC20)

The optimum bitumen content for ACWC 20 is 4.89%. This OBC are determined from Bulk Density, Air Voids, and Marshall Stability. The highest point in graphs will be taken for Bulk Density and Marshall Stability. The lowest point in the graphs will be taken for air voids.

4.5. Indirect Tensile Strength

Table 4.3 Tensile Strength Properties for AC14

Sample identification ACWC14		Dry Samples		
Diameter, mm (in.)	D	103.92	104.03	103.68
Thickness, mm (in.)	t	59.29	59.24	59.54
Dry mass in air, g	A	1198.70	1193.60	1194.60
SSD mass, g	B	1202.20	1199.80	1198.40
Mass in water, g	C	691.80	693.50	694.50
Volume (B – C), cm3 E	E	510.40	506.30	503.90
Bulk specific gravity (A/E)	Gmb	2.35	2.36	2.37
Maximum specific gravity	Gmm	2.45	2.43	2.51
% air voids [100(Gmm – Gmb)/Gmm]	Pa	4.14	2.98	5.55
Volume of air voids (PaE/100), cm3	Va	21.13	15.11	27.96
Load, kN (lbf)	P	15.61	14.60	15.77
Saturated min @ kPa (psi) or mmHg (in.Hg)				
Diameter, mm (in.)	D'	103.99	103.58	103.66
Thickness, mm (in.)	t′	59.33	58.55	58.94
SSD mass, g	B′	1203.20	1199.50	1203.40
Dry mass in air, g	A'	1198.30	1194.50	1198.70
Volume of absorbed water (B′ – A'), cm3	J'	4.90	5.00	4.70
Volume of air voids (PaE/100), cm3	Va	12.18	13.85	15.66
% saturation (100J′/Va)	S′	40.23	36.10	30.01
Load, N (lbf)	P′	8.50	6.77	7.44
Dry strength [2000P/πtD (2P/πtD)], kPa (psi)	S1	98.73	86.37	100.77
Wet strength [2000P′/πt′D (2P/πt′D)], kPa (psi)	S2	29.27	18.57	22.43
Visual moisture damage (0 to 5 rating)		4	5	5
Cracked/broken aggregate?		Broken	Broken	Broken
TSR (S2/S1)		30%	22%	22%

Table 4.4 Tensile Strength Properties for AC20

Sample identification ACWC20		Dry Samples		
Diameter, mm (in.)	D	104.03	105.27	105.33
Thickness, mm (in.)	t	61.09	61.31	62.05
Dry mass in air, g	A	1232.10	1202.58	1203.50
SSD mass, g	B	1236.50	1208.60	1208.40
Mass in water, g	C	712.90	705.70	706.50
Volume (B – C), cm3 E	E	523.60	502.90	501.90
Bulk specific gravity (A/E)	Gmb	2.35	2.39	2.40
Maximum specific gravity	Gmm	2.45	2.43	2.51
% air voids [100(Gmm – Gmb)/Gmm]	Pa	3.95	1.59	4.47
Volume of air voids (PaE/100), cm3	Va	20.70	8.01	22.42
Load, kN (lbf)	P	20.60	18.50	19.63
Saturated min @ kPa (psi) or mmHg (in.Hg)				
Diameter, mm (in.)	D'	105.89	105.42	105.96
Thickness, mm (in.)	t’	62.22	62.03	61.58
SSD mass, g	B’	1240.10	1238.39	1235.39
Dry mass in air, g	A'	1237.21	1233.50	1231.23
Volume of absorbed water (B’ – A'), cm3	J'	2.89	4.89	4.16
Volume of air voids (PaE/100), cm3	Va	15.64	16.87	18.66
% saturation (100J’/Va)	S’	18.48	28.99	22.29
Load, N (lbf)	P’	13.71	14.68	15.63
Dry strength [2000P/πtD (2P/πtD)], kPa (psi)	S1	171.94	138.67	156.13
Wet strength [2000P’/πt’D (2P/πt’D)], kPa (psi)	S2	76.16	87.32	98.98
Visual moisture damage (0 to 5 rating)		4	5	5
Cracked/broken aggregate?		Broken	Broken	Broken
TSR (S2/S1)		44%	63%	63%

The indirect tensile strength test is used to evaluate the bituminous mixture's tensile properties. The primary objective of the present research is to examine the effect of filler materials and test temperature on the tensile properties and moisture susceptibility of bituminous concrete mix prepared with stone dust and cement as filler materials. By using temperature, Marshall stability, and optimal bitumen content as independent variables for every filler material, a prediction model for indirect tensile strength was developed.

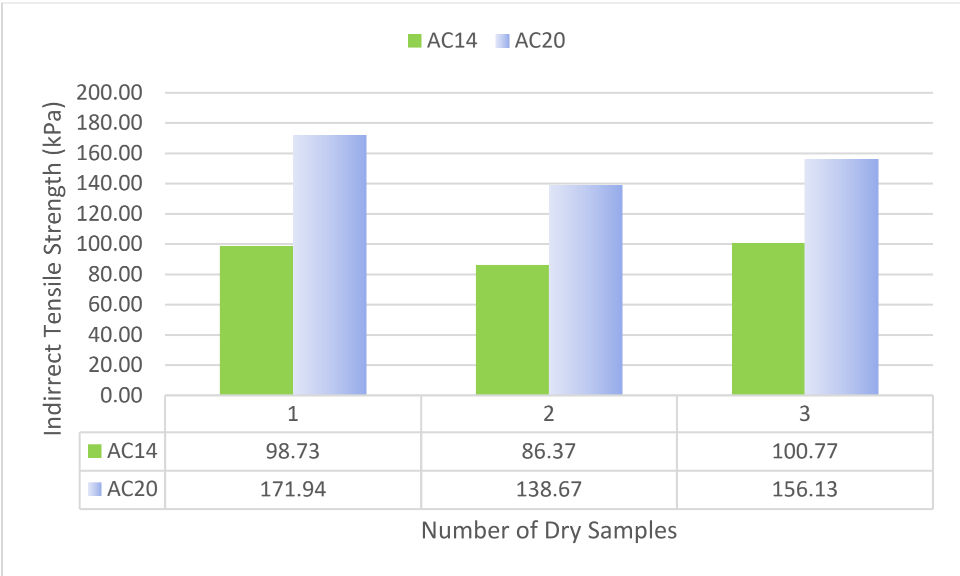


Figure 4.4 ITS vs Number of Dry Samples

The dry strength of the sample was evaluated using a total of 6 samples: 3 samples for ACWC 14 and 3 samples for ACWC 20. ACWC 14 has determined the dry strength to be 98.73 kPa. 86.37 kPa and 100.77kPa. ACWC 20 determined the dry strength to be 171.94 kPa, 138.67 kPa, and 156.13 kPa. The difference between ACWC 14 and ACWC 20 is substantial. Based on this data, ACWC 14 have a lower strength than ACWC 20. When an average load of 15kN is applied on ACWC 14, the specimens will fracture due to poor bonding. ACWC 20 have a greater tensile strength when more than 5kN of load is applied. During the preparation phase, the test sample was maintained at 60 °C. Temperature is one of the factors affecting the tensile strength of specimens, with the tensile strength increasing with decreasing temperature to a maximum value that is roughly the same for all asphalts in newly constructed roads at low temperatures.

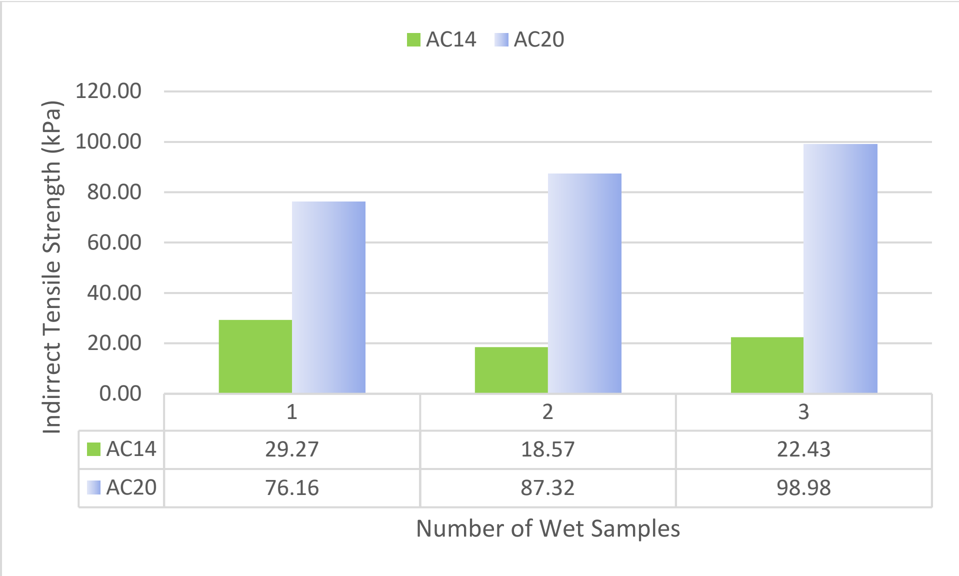


Figure 4.5: ITS vs Number of Wet Samples

The wet strength of the samples have significant lower strength compared to dry sample. The wet sample undergoes freezing about 16 hours and soaking into hot water at 60°C about 24 hours. Hence, the bonding between the bitumen is poor and easily broken.

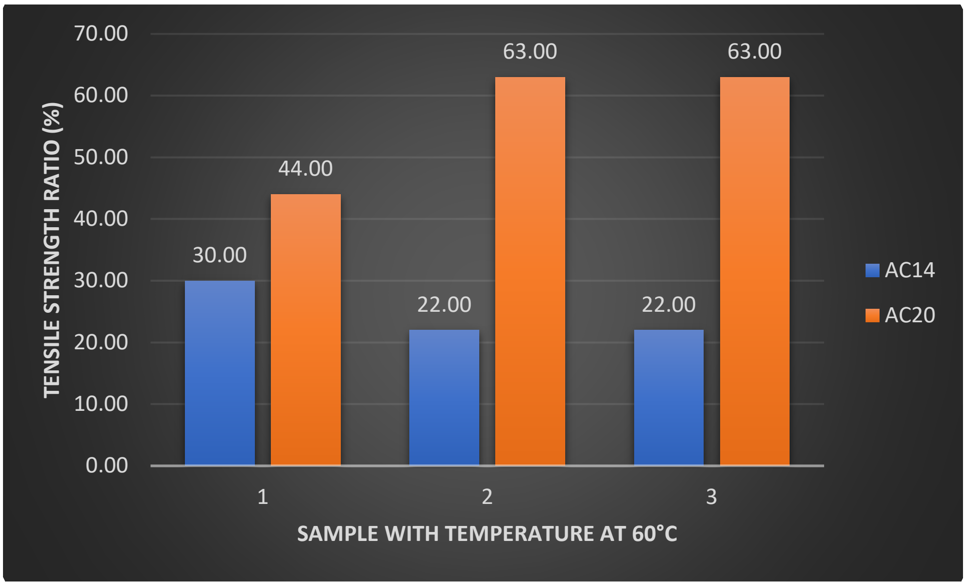


Figure 4.6 TSR vs Freeze and Thaw

The relaxing ability of all considered bitumens, both clean and modified, is reduced by cyclic freezing and thawing. For example, the sample was frozen and thawed at 0 °C and soaked at 60 °C, satisfying the superpave condition. From the result, TSR for

AC14 are lower and slight decrease in the average of test samples. TSR for AC20 are higher than AC14 and increased from 44% to 63%. AC20 has a stable tensile strength.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1. Conclusion

The objectives of this study which is to determine the Marshall properties for JKR and LLM specification and investigate the mechanical properties of ACWC14 and ACWC20 in order to know the differences and the efficiency.

The test will be conducted through Indirect Tensile Strength Test (IDS), Indirect Tensile Fatigue Test (ITFT), Repeated Load Axial Test (RLAT) and Indirect Tensile Stiffness Test Modulus (ITSM) to determine the maximum resistance towards Fatigue, Rutting (permanent deformation) and the stiffness of the pavement. This is aim to identify the pavement durability or pavement stability between ACWC 14 and ACWC 20. Due to the time consumption and workability of testing machines, the test were conducted with Marshall Stability Test and Indirect Tensile Test only.

- Only hot mix asphalt paving mixtures that use penetration or viscosity graded asphalt cement and contain aggregates with maximum sizes of 25 mm (1 in) or smaller can use the Marshall method as it is provided here. This approach is only applicable to hot mix asphalt paving mixtures. This technique is meant to be used in the laboratory for the design of asphalt hot mix pavement. The Marshall Method begins with the preparation of the test specimens as the first step in the method. after that, heating, mixing and compacting asphalt aggregate mixture The two principles of the Marshall method of mix design are density, voids, analysis and stability vs flow test of the compacted test specimens
- Depending on the test method, a variety of problems were noted, including test complexity, inadequate methods for sample conditioning, a high rate of dispersion in test findings, and/or issues separating connected elements affecting test results.

- Tensile Strength Test cannot discriminate between adhesion and cohesion qualities, but are used to evaluate the quality of various bitumen products.

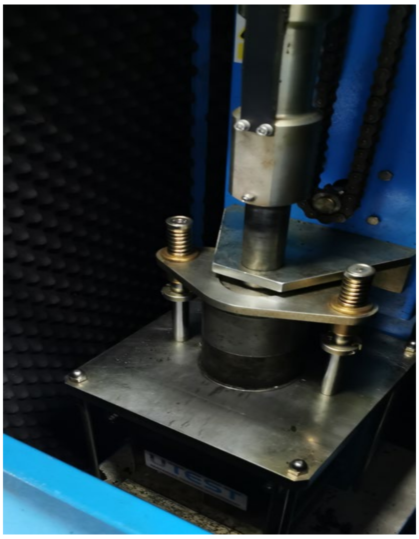
- maximum compressive strength noted on the testing machine, and continue loading until a vertical crack appears. Interior surface were inspected for evidence of cracked or broken aggregate; visually estimate the approximate degree of moisture damage on a scale from

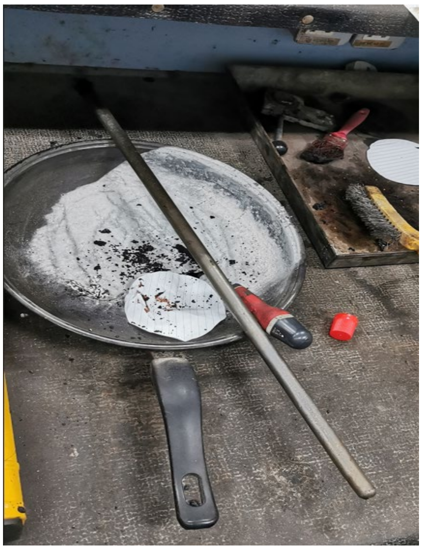
- AC20 has a higher value of Marshall stability and also high tensile strength. This has shown LLM is using the high quality of asphalt pavement and standardized AC20 to construct in most of the highway in Malaysia

5.2. Recommendation

- In order to reduce the fracture in the specimens, size of aggregate and percentage of bitumen used need to be modified.
- Further study on the mechanical properties and behaviour of asphalt concrete.
- It is recommended that an experimental validation of the optimized results be performed to check the accuracy of the developed model

APPENDIXES



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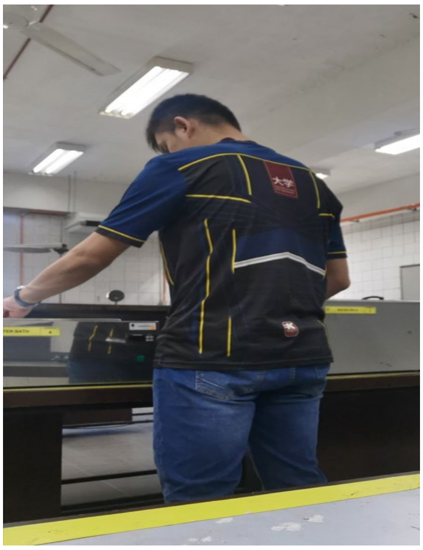

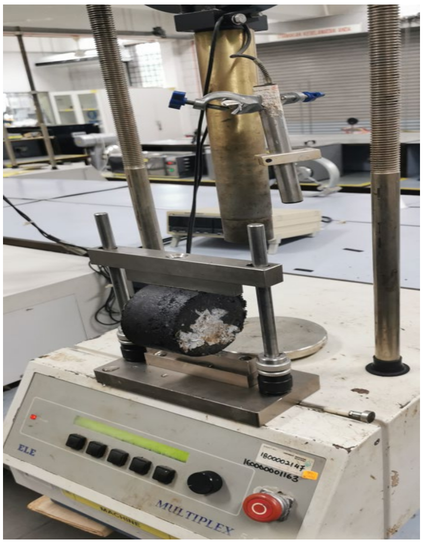
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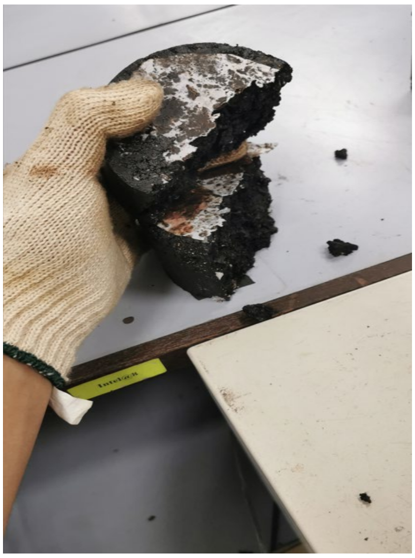

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