EVALUATION OF FIBER REINFORCED ASPHALT MIXTURES AND SENSITIVITY ANALYSIS FOR AIRPORT PAVEMENT MAINTENANCE AND REHABILITATION PRACTICES

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ABSTRAK

Di Malaysia, penggunaan gentian sebagai bahan campuran dalam sebagai campuran asfalt adalah salah satu pilihan untuk memanjangkan hayat turapan. Penggunaan gentian seperti Super Fiber Mix (SFM) telah meliputi lebih daripada 3.3 juta kawasan persegi untuk pembinaan jalan raya. Walau bagaimanapun, aplikasi SFM dalam pembinaan landasan masih terhad. Atas sebab itu, terdapat laporan terhad yang membincangkan kesan SFM terhadap gradasi penggunaan konkrit asfalt (ACWC 20) PLUS dan gradasi penggunaan konkrit asfalt Jabatan Kerja Raya Malaysia (ACBC 28). Penggredan ini menyediakan sokongan struktur turapan yang baik untuk menampung beban pesawat. Dalam penyelidikan ini, campuran asfalt konvensional dan campuran asfalt diubah suai telah disediakan. Campuran asfalt konvensional gred penembusan 60/70 digunakan sepanjang kajian. Reka bentuk campuran Marshall telah dijalankan untuk menentukan Kandungan Pengikat Optimum (OBC) untuk kedua-dua ACWC20 dan ACBC28. OBC untuk ACWC20 dan ACBC28 masing-masing ialah 5.1% dan 4.6%. Pada OBC yang sama, SFM telah ditambah untuk mengukuhkan campuran asfalt. Campuran asfalt diubah suai telah dicampur dengan SFM yang terdiri daripada serat poliolefin dan aramid yang menyumbang kurang daripada 0.1% daripada jumlah berat campuran. Beberapa ujian dijalankan untuk menilai prestasi bahan tambahan SFM kepada campuran asfalt. Ujian tersebut ialah ujian Kestabilan dan Aliran Marshall, Ujian Kekuatan Tegangan Tidak Langsung, Ujian Modulus Daya Tahan dan Ujian Pengesanan Roda Hamburg. Semua ujian makmal telah membuktikan bahan tambahan SFM dalam campuran asfalt telah meningkatkan prestasi campuran. Kestabilan asfalt diubah suai, MA adalah 20% dan 35% lebih besar daripada asfalt konvensional, CA untuk ACWC20 dan ACBC28 masing-masing. Nilai aliran asfalt diubah suai adalah lebih rendah daripada asfalt konvensional kerana penambahan SFM telah meningkatkan rintangan ubah bentuk campuran asfalt. Nilai ITS untuk MA meningkat sebanyak 39% dan 30% untuk ACWC20 dan ACBC28 masing-masing. SFM telah meningkatkan rintangan asfalt terhadap keretakan. Dalam ujian modulus daya tahan, modulus daya tahan asfalt diubah suai adalah 30% dan 31% lebih baik daripada asfalt konvensional untuk ACWC20 dan ACBC28 masing-masing. Tambahan pula, kedalaman alur MA dan CA masing-masing adalah 4.72mm dan 6.60mm yang menunjukkan MA mempunyai rintangan alur yang lebih baik daripada CA. Selain itu, analisis Sensitiviti FAARFIELD dijalankan untuk menentukan kesan ketebalan lapisan turapan dan nilai modulus ke atas hayat turapan (tahun). Hasil daripada perisian analisis menunjukkan bahawa ketebalan turapan mempunyai kesan yang ketara kepada hayat turapan. Semakin tebal ketebalan turapan, semakin tinggi jangka hayat turapan. Peningkatan ketebalan lapisan haus sebanyak 0.6 inci mampu memanjangkan hayat turapan lebih daripada 10 tahun daripada analisis ketebalan FAARFIELD. Di samping itu, jangka hayat turapan meningkat apabila modulus daya tahan turapan meningkat. Dalam analisis modulus daya tahan, nilai modulus 33.5% lebih tinggi bagi lapisan haus menghasilkan lebih tinggi hayat turapan dengan 7.3 tahun. Data mendedahkan bahawa penambahan SFM yang meningkatkan modulus keanjalan telah meningkatkan hayat turapan. Kesimpulannya, semakin tinggi modulus daya tahan turapan, semakin lama hayat turapan.

ABSTRACT

In Malaysia, use of the fiber as a modifier in asphalt mixtures is one of the options to prolong pavement life. Application of the fiber such as Super Fiber Mix (SFM) has covered more than 3.3 million square areas for road construction. However, the applications of the SFM in runway construction are still limited. For that reason, there are limited reports that discussed the effects of the SFM on the PLUS asphalt concrete wearing course (ACWC 20) and Malaysian Public Work Department's asphalt concrete binder course (ACBC 28) gradations. These gradations provide good pavement structural support to cater to aircraft loads. In this research, the conventional asphalt mixture and modified asphalt mixture were prepared. Conventional asphalt mixture 60/70 penetration grade is used throughout the study. Marshall mix design was carried out to determine the Optimum Binder Content (OBC) for both ACWC20 and ACBC28. The OBCs for the ACWC20 and ACBC28 is 5.1% and 4.6% respectively. At the same OBCs, the SFM was added to reinforced asphalt mixture. Modified asphalt mixture is modified with SFM which consists of polyolefin and aramid fibers which contribute less than 0.1% of the total weight of the mixture. Several tests are carried out to evaluate the performance of SFM additives to the asphalt mixture. The tests are Marshall Stability and Flow test, Indirect Tensile Strength Test, Resilient Modulus Test, and Hamburg Wheel Tracking Test. All laboratory tests have proved the additive of SFM in asphalt mixture has improved the mixture performance. The Marshall Stability of modified asphalt, MA is 20% and 35% higher than conventional asphalt CA for ACWC20 and ACBC28 respectively. The flow value of modified asphalt is lower than conventional asphalt as the addition of SFM has increased the deformation resistance of the asphalt mixture. The ITS value for MA increased by 39% and 30% for ACWC20 and ACBC28 respectively.

The SFM has improved the asphalt resistance to cracking. In resilient modulus test, the resilient modulus of modified of modified asphalt is 30% and 31% better than conventional asphalt for ACWC20 and ACBC28 respectively. Furthermore, the rut depth of MA and CA are 4.72mm and 6.60mm respectively which indicates MA has better rutting resistance than CA. Additionally, Sensitivity analysis of the FAARFIELD was carried out to determine the effect of pavement layer thicknesses and modulus values on the pavement life (year). The result of the analysis software shows that the thickness of pavement has a significant impact on pavement life. The thicker the pavement thickness, the higher the pavement life. Increasing the thickness of wearing course by 0.6 inches can extend the pavement life by more than 10 years from the thickness analysis of FAARFIELD. On the other hand, the pavement life increased as the resilient modulus of pavement increased. In the resilient modulus analysis, 33.5% higher modulus value of wearing course resulted in 7.3 years higher pavement life. The data reveals that the addition of SFM which improved the resilient modulus has increased the pavement life. In short, the higher the resilient modulus of pavement, the longer the pavement life.

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LIST OF ABBREVIATIONS

AR	Aramid
ASU	Arizona State University
CA	Conventional Asphalt
FAA	Federal Aviation Administration
HL	Hydrated Lime
HMA	Hot Mix Asphalt
ITS	Indirect Tensile Strength
ITT	Indirect Tension Test
MA	Modified Asphalt
M&R	Maintenance and Rehabilitation
OBC	Optimum Binder Content
PP	Polypropylene
PWD	Public Works Department of Malaysia
SFM	Super Fiber Mix
SSD	Saturated surface dry
VFB	Voids in Aggregates Filled by Bitumen
VMA	Voids in Mineral Aggregates

CHAPTER 1

INTRODUCTION

1.1 Background

Airplane is one of the most widely used modes of transportation for connecting people all over the world. Airport is a key indicator of a country's economic and social circumstances. The number of people using aircraft for transportation is increasing every year, necessitating increased traffic volumes and aircraft loads of airport. To assure good serviceability and provide suitable maintenance solutions for pavements, more effective methods for pavement monitoring and structural evaluation are necessary.

To increase pavement performance, fiber is introduced to asphalt mixtures as an additive. Fiber can raise the bitumen's softening point, making the reinforced bitumen harder than the original bitumen. Fiber is added to asphalt concrete mixtures to enhance bitumen characteristics and minimize bitumen drainage which will lower bitumen content and increase slippery resistance (Mirzaei, 2016). The fibers increase the bitumen cover on aggregates which will cause bitumen hardening and improves bitumen properties. Furthermore, compared to unmodified mixes, fiber-modified mixtures have more resistant fibers to cracking, fatigue, and moisture.

In this study, Super Fiber Mixture (SFM) was proposed to be used in Fiber Reinforced Asphalt Mixture. SFM is a synthetic fiber mixture with a high tensile strength that is used to reinforce asphalt mixes in both new and rehabilitation projects (AHN VERTEX SDN BHD, 2022). The combination of aramid and polyolefin fibers is intended to improve the mix design of asphalt. Aramid fibers are noted for their strength and durability in both high and low temperatures and will not melt in the asphalt mix. Besides, SFM can save money in short term by reducing the thickness of the pavement layer while maintaining the same durability as traditional mixes. It also can save money over time by prolonging the life of the pavement when it is placed at a conventional pavement thickness.

Airport pavement generally can be divided into three sections which are apron, taxiway, and runway. This study focused on the use of Fiber Reinforced Asphalt Mixture on runway. SFM was added in wearing course and binder course to enhance the strength of runway. ACWC20 and ACBC28 gradation were used to evaluate the performance of fiber in asphalt pavement. The experiment was designed to test the asphalt in aged and unaged conditions. The main purpose of this study was to compare conventional asphalt and modified asphalt which is fiber-reinforced in terms of sensitivity and the effectiveness of fiber on increase the life span of pavement. The carried-out experiments are Marshall Stability and Flow test, Resilient Modulus test, Indirect Tensile Strength test (ITS), and Wheel Tracking test.

Next, sensitivity analysis of performance for flexible pavement can be used to study the influence of thickness and resilient modulus of pavement, which can help optimize the design and performance evaluation of the pavement structure. In this research, ACWC20 and ACBC28 with SFM were selected to study the sensitivity of traffic and material parameters based on FAARFIELD software. FAARFIELD is the standard thickness design and pavement strength evaluation software. This software is used to determine the effect of pavement thickness and resilient modulus on pavement life. The objective of this research is to identify the influence of pavement thickness and resilient modulus on pavement life and the effect of SFM on asphalt mixture performance.

1.2 Problem Statement

Airport pavements are frequently influenced by aircraft landing and taking-off, which are major factors in pavement failures such as surface shoving and slippage cracking. In addition, high ambient and in-pavement temperatures and excessive moisture content have significant impact on pavements. All the factors can easily lead to pavement deterioration or pavement failure.

Pavement failure happens when an asphalt surface loses its original shape and generates material stress that causes other problems to occur (Lone Star Paving, 2017). Cracking, potholes, depressions, rutting, shoving, upheavals, and raveling are signs of pavement deterioration. Lifetime of pavement can be shortened due to the impact of pavement failure. To prevent cracks from spreading or forming, adequate maintenance such as crack and asphalt sealing is essential.

Fiber is one of the additives that can improve the service life of asphalt pavement. However, the major problem is that the impact of fiber on the service life of airport pavement is still uncertain. There is lack of detailed information regarding the influence of SFM which consists of aramid fiber and polyolefin fiber on ACWC 20 and ACBC28 which are usually used as gradation for airport pavement. Hence, it is questionable on the effect of SFM application on the service life improvement of airport runway pavement.

1.3 Objective

The aim of this research is to determine the effectiveness of SFM to be used as an additive in airport runway pavement to increase the pavement life span by comparing it to conventional pavement. The specific objectives of this study are:

1. To propose suitable mix design for wearing course and binder course for airport runway application.

2. To assess the effectiveness of the SFM in asphalt mixture as compared to conventional asphalt mixture based on laboratory tests.

3. To determine the effects of the remaining life of pavement layers by using FAARFIELD software due to changing layer thicknesses and modulus values under stipulated aircraft loads

1.4 Scope of Work

This research intends to characterize the physical and mechanical properties of conventional mixtures and fiber-reinforced mixtures. This study begins with the preparation of raw material which consists of granite as aggregate, a binder with penetration grade of 60/70, and fiber which consists of polyolefin and aramid. Before the preparation of the mixture sample, Marshall Mix Design determines the optimum binder content (OBC) for the mixtures. Conventional mixture and fiber-reinforced asphalt mixture for ACWC20 and ACWC28 were prepared to undergo four tests which are Marshall Stability and Flow test, Resilient Modulus test, Indirect Tensile Strength test (ITS), Wheel Tracking test. Lastly, the efficiency of Super Fiber mixture (SFM) in modified asphalt mixture was evaluated through the tests and compared to the test results of conventional mixtures. Sensitivity analysis was carried out through the FAARFIELD software to determine the effect of pavement thickness and resilient modulus on the pavement service life. Figure 1.1 shows the research methodology in flow chart.

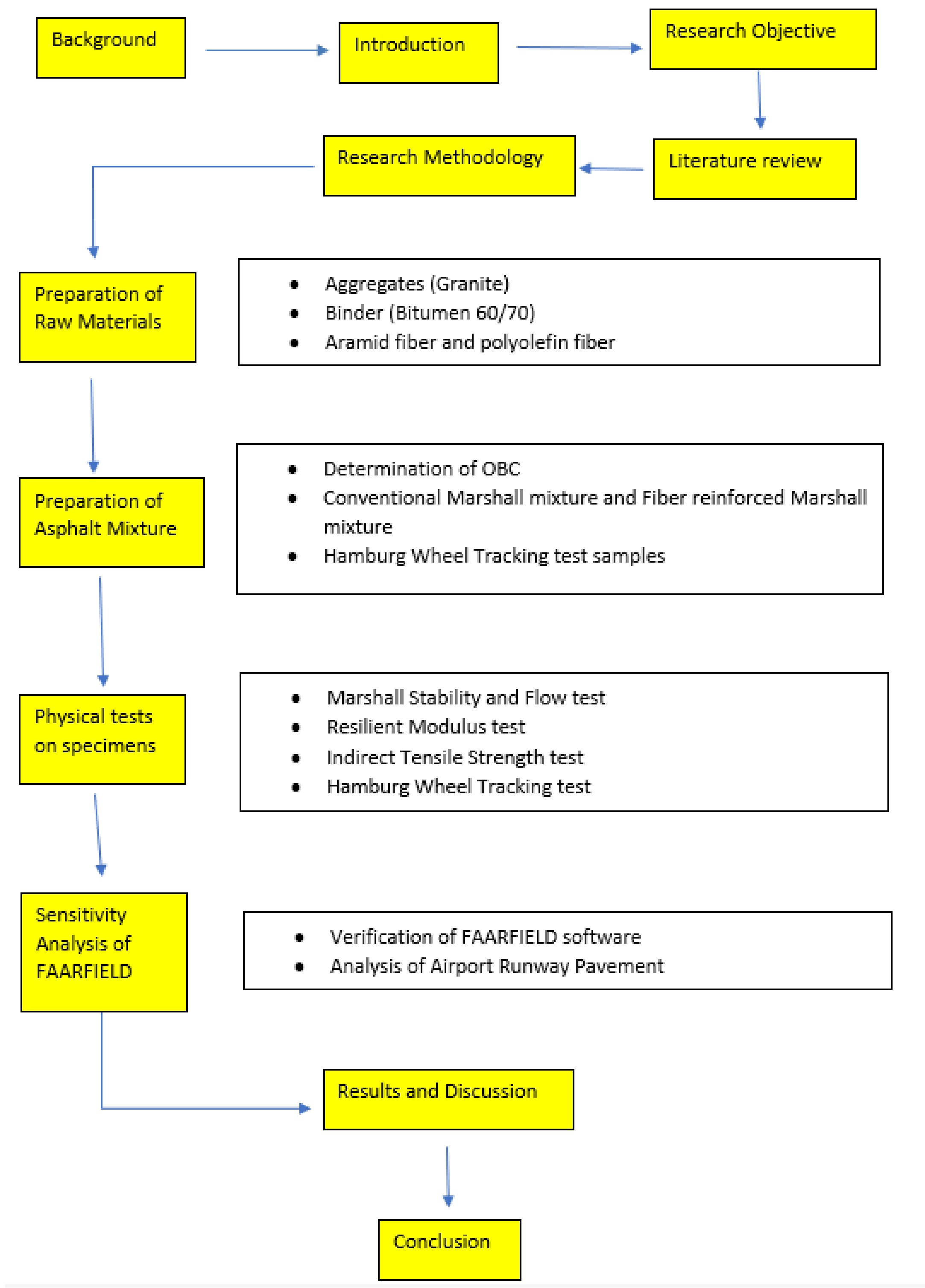

Figure 1.1: Research methodology

1.5 Significance of Study

The number of aircraft on the airport's pavement keeps rising dramatically, which raises the traffic volumes. Significant higher traffic volume accelerated the deterioration of pavement quality for both the pavement surfaces and the pavement structure after a period of time. Because of this, high-quality asphaltic pavement is necessary to address the condition and increase the pavement's lifespan. Several studies had been done and SFM is proposed due to its potential in improving the performance and durability of the asphaltic pavement. Ziari et al., (2019) have shown how polyolefin-aramid fibers added to modified asphalt can significantly improve the quality of the asphalt surface road. The improvement of rutting, fatigue, and cracking performance enables the pavement will endure longer under recurrent traffic loads and require fewer frequent maintenance and rehabilitation treatments.

Thus, in this research, the performance of SFM will be evaluated by physical tests for airport pavement which is different gradation from highway pavement. This research is significant to show the impact of SFM on the service life and performance of airport pavement.

Besides, the pavement thickness and resilient modulus have significant impact on the pavement life. It is important to understand the effect of pavement thickness and resilient modulus in airport pavement design. Hence, this research has conducted an analysis through FAARFIELD software to find out the life span of pavement by altering the pavement thickness and resilient modulus. The analysis result contributes to effective pavement design by achieving the ideal pavement life with optimum pavement thickness and resilient modulus. Airport pavement designed with high life span can save cost by reducing the pavement maintenance and rehabilitation practices.

1.6 Organization of Dissertation

This dissertation illustrates the introduction of research, literature review, materials used, and methodology applied for this study. Results from tests, study findings, discussions, conclusions, and recommendations based on the conducted laboratory experimental works are also presented. There are five chapters in this dissertation, including Introduction, Literature Review, Research Methodology, Results and Discussions, and Conclusion and Recommendations.

Chapter One discussed the background for the research study, problem statement that identified the problem in the current environmental issues and technology, objectives to be achieved in this study, the scope of work, and the study's significance.

Chapter Two involved a collection of literature reviews consisting of past research findings relating to asphalt application in airport pavement, pavement failure, the importance of airport pavement maintenance and rehabilitation practices, effect of using fiber on the durability of asphalt pavement, mechanical performance of fiber in hot mix asphalt, optimum binder content for ACWC20 and ACBC28, and effect of pavement thickness and resilient modulus to pavement service life .

Chapter Three described the materials used and methods of preparation to accomplish the research objectives. The conducted physical tests in evaluating the physical and mechanical properties of asphalt mixture were discussed. The way to analyze the airport pavement by using FAARFIELD software was described in this chapter as well.

Chapter Four presented the results obtained from the tests conducted and discussion based on the collected laboratory data. The results of physical tests and characterization for conventional mixture and Super Fiber mixture were analyzed. The result of FAARFIELD analysis result was shown in this chapter. It was discussed in detail and included in this chapter.

Chapter Five concluded the discussion that had been determined throughout the entire research study. The conclusion highlighted the key findings that meet the research objective.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Asphalt mixture used in airport pavement is a temperature-sensitive material, the temperature changes of asphalt mixture will have a significant impact on its mechanical properties and operational performance. When the temperature is high, the binder's viscosity drops substantially, as does the adhesion between the aggregates. This phenomenon causes the asphalt mixture's stiffness degrades, resulting in a huge cumulative and irreversible deformation with each repeat loading. Thus, asphalt pavement structure will compress and rut in high-temperature circumstances. On the other hand, when the temperature drops, the strength and thermal stress in the asphalt mixture may increase together. As consequence, the thermal stress will sometimes exceed the strength of asphalt mixture and thus cause thermal cracking. Other asphalt pavement distresses, such as fatigue cracking, reflective cracking, and so on, are similarly linked to the temperature of the asphalt mixture, either directly or indirectly (Sun, 2016).

In order to counter the asphalt pavement distress, the quality of asphalt mixture can be improved by adding commercially available additives. The modification provides a chance to enhance the inadequate qualities of asphalt mixes and maximize their performance in comparison to the existing standard. It tends to produce asphaltic concrete with improved properties such as rutting resistance, thermal cracking resistance, aging resistance, permanent deformation resistance, stripping resistance, moisture damage resistance, and so on.

For the purpose to increase the quality of asphalt concrete, various additional materials such as fine fillers, aggregates, fibers, polymers, and so on are utilized. The addition of fibers to asphalt mixture enhances material strength and fatigue characteristics. Due to their inherent compatibility with asphalt concrete and excellent mechanical properties, fibers offer excellent potential for modification of asphalt concrete mix.

Ziari et al., (2019) conducted a study of the effect of polyolefin-aramid fibers on the performance of hot mix asphalt. The fibers were added in different percentages of the total weight of the asphalt mixture. About 0.025%, 0.05%, and 0.75% fibers were added to asphalt mixture while the unmodified mixture was used as a control. Mixtures containing polyolefin-aramid fibers were found to have higher resistance in pavement distress. Besides, the research result showed that the higher the amount of polyolefin-aramid fibers added to the mixture, the higher the resistance of the asphalt mixture to rutting, fatigue, and cracking. Hence, polyolefin-aramid should try to be employed to improve the mechanical properties of asphalt mixes.

This chapter established a brief understanding of the effect of using fiber on the durability of asphalt pavement. The strategies for ensuring that the asphalt reinforced bituminous mix develops appropriate strength in terms of physical and mechanical capabilities were studied and addressed.

2.1 Airport Asphalt Pavement and Its Failure

Asphalt pavement is used at the majority of airports. There are several regions in airports, such as runways, taxiways, aprons, and parking spaces. The needed gradation for each might be different, especially for wearing courses. Puncturing, gasoline, and chemical agent resistance are required for parking and aprons while good skid resistance is required for other surfaces. These diverse needs can be met with asphalt mixtures. Asphalt mixes are widely used in the surfacing of runways and aircraft handling areas on a wide range of airfields, from international airports regularly used by the heaviest airliners to military airfields carrying high-performance jet aircraft, to smaller domestic airfields regularly used by light or medium-sized aircraft, to the smallest private airfield used by light single or twin-seat aircraft (European Asphalt Pavement Association, 2003)

Determining whether a pavement has failed is one of the most difficult aspects of pavement examination. The FAA design techniques are calibrated using full-scale test results with clearly specified failure criteria. Shear failure in the subgrade causes a 1-inch upheaval at the pavement surface, which is known as flexible pavement failure. Full-depth cracking in 50% of the slabs will be considered rigid pavement failure (Federal Aviation Administration, 2004).

Pavement deteriorates when the surface can no longer maintain its original shape and has problems due to material stress. Examples of pavement failure are cracking, potholes, depressions, rutting, shoving, upheavals, and raveling. The cause of pavement failure can be low quality of materials and insufficient pavement maintenance. In order to overcome pavement failure, sufficient pavement maintenance and rehabilitation practices and the adoption of soil cement stabilization have frequently given the needed quality in terms of prevention of failure. (Akeem, 2022)

2.2 The Importance of Airport Pavement Maintenance and Rehabilitation Practices

Airfields and highway networks, which include both streets and roads, represent a significant public investment. They are also the foundation of one of the most essential economic activities in modern industrialized societies: transportation of commodities and people. Preserving this investment and keeping it in good working order so that it can continue to serve its purpose is certainly a worthwhile goal. However, time and use have taken their toll on these pavement constructions, and an increasing number of them are nearing or have passed their designed life. As a result of this degradation, entities in charge of pavement management have begun to shift their focus away from the building of new pavements but toward the maintenance and rehabilitation (M&R) of existing pavements (Gendreau & Soriano, 1998)

Any maintenance program should aim to deliver a safe and functional pavement system at the lowest possible cost. A successful maintenance program will offer the owner enough information to determine how to get the most return on their investment. A good pavement maintenance management program outlines the steps that the airport director should follow to ensure adequate pavement care. This encompasses both preventative and corrective measures. Key parts of the program must be addressed to properly track pavement care operations. To succeed in any project, the owner must commit to allocating appropriate resources to the maintenance program (Federal Aviation Administration, 2022). Pavement will degrade more quickly if minor cracks are not addressed regularly, and the cracks will only become bigger. Investing in crack sealing and other kinds of pavement care is more cost-efficient than replacing your pavement prematurely (Cactus Asphalt, 2016).

2.3 Effect of Fiber on the Durability of Asphalt Pavement

The following subchapters will describe the effect of polyolefin and aramid fiber on the quality of the asphalt mixture. The literature review on the effect of asphalt mixture will be verified by the laboratory tests that have been carried out.

2.3.1 Marshall Stability

Engineers are always looking for new ways to improve the performance of flexible pavements. Rutting and fatigue cracking are the two most common kinds of surface deterioration that cause maintenance and interruption. Many experiments have been conducted to date to solve these challenges, ranging from modifying gradation to adding polymers and fibers to the asphalt mixture. Polyolefin additive was used as a fiber addition in the study of Akmaz & Celik (2020) because of its inexpensive cost and high association with asphalt pavement.

According to the study, waste plastics made of polypropylene (PP) and high-density polyethylene (HDPE) were co-pyrolyzed at temperatures between 300 and 350 °C. Polyethylene and polypropylene are common examples of polyolefin (Labelplanet, 2022). With the Marshall apparatus, two distinct HMA sample series were created using pure and 5% PP-HDPE modified bitumen. Tests on Marshall stability and flow have been carried out in the research. The Marshall stability of the modified HMA was found to rise by between 8.5 and 13% when compared to the pure HMA.

The reason behind that is the bridging effect of fiber. In the fiber bridging phenomenon, the fibers of adjacent plies bridge the delamination plane and act as crack arrestors due to which the delamination resistance and inter-laminar fracture toughness increase (Khan, 2019). Thus, Marshall stability of the asphalt mixture will be increased due to the increased delamination resistance and inter-laminar fracture toughness under the presence of fiber.

2.3.2 Indirect Tensile Strength (ITS)

ITS is used to determine the tensile properties of the asphalt mixture, which are associated with the cracking qualities of the pavement. A higher ITS corresponds to a stronger cracking resistance. At the same time, asphalt mixtures that can withstand greater strains before failing are more likely to be resistant to cracking than those that cannot withstand high strains. Besides, the Pavement Mechanistic-Empirical (ME) Design Guide's transverse cracking model uses ITS as a key input parameter. ITS is a metric for asphalt pavement's ability to withstand low-temperature cracking. This value is often calculated using Indirect Tensile (IDT) samples in the lab and entered as an input parameter in the design guide (Rashadul et al, 2015)

A study has been done (Slebi-Acevedo et al, 2020) to study the effect of polyolefin-aramid and polyacrylonitrile fibers on the indirect tensile strength of fiber-reinforced asphalt mortars. The proportion of the polyolefin-aramid (POA) fibers is 86% of polyolefin and 14% of aramid fibers. From the study result, in comparison to the samples without fibers, adding fibers to the mortar raises the ITS values. When the impact of fiber content on the outcomes is analyzed, it is clear that rising fiber content is accompanied by rising ITS values. In terms of POA fibers, the samples that contain 0.3% of POA fibers showed the greatest improvement. Additionally, additions of 0.1 and 0.2 percent of POA fibers led to improvements of 16.50 and 18.04 percent of ITS. The study has proven the POA fibers can increase the ITS of asphalt mixture.

2.3.3 Resilient Modulus

According to Wibisono & Nikraz (2019), the resilient modulus (MR) is a characteristic that measures the material's stiffness when designing the thickness of an asphalt pavement. Since it is regarded as effective and more practical in most applications, the value is typically computed from an Indirect Tensile Test (ITT), which only requires a single loading time and temperature.

Takaikaew et al. (2021) have done research on the effect of polyolefin-aramid fibers on the resilient modulus of asphalt mixture. This study uses laboratory and field investigations to examine the mechanical properties of fiber-reinforced asphalt concrete (FR-AC) in comparison to conventional AC (without fiber-reinforcement) with various binders (AC60/70 and PMA). To evaluate the scale impact on the geotechnical properties and performance of AC, the mixing quality of FR-AC in both the laboratory and the plant was also investigated. From the study result, the resilient modulus of laboratory mix with fiber is 33.7% higher than the conventional mix. The polyolefin-aramid fibers have improved the resilient modulus of mix from plant by 27.3%. The laboratory and field trial experiments have demonstrated the viability of using fiber reinforcement to enhance the engineering characteristics and functionality of conventional AC pavement.

According to Ali & Mohod (2015), The addition of SFM increases the resilient modulus of asphalt mixture because polyolefin and aramid fibers can improve the composite mixture's ductile and flexural toughness. The increased flexural toughness enables the composite mixture to have higher resistance to fatigue crack and thus the resilient modulus is increased.

2.3.4 Rut Depth

One of the most common early problems with asphalt pavements is rutting, which not only seriously compromises the road's quality of service and lifespan but also puts drivers' safety in danger. Through analysis, it was shown that one of the primary causes of the early distresses in asphalt pavement is the poor construction quality of the asphalt layer (Zhao & Gao, 2021). To evaluate the rutting resistance and moisture resistance of pavement, Hamburg Wheel Tracking (HWT) test will be carried out. The commonly used test standard is AASHTO-T324, while many states alter this process to suit their unique needs.

Munir et al. (2021) conducted a study to identify the variables influencing the performance of asphalt mixes reinforced with aramid fiber. There were two different aramid fiber types in the test plan (Fiber A: wax-treated aramid fibers and Fiber B: a blend of aramid and polyolefin fibers). In this study, the Hamburg Wheel Tracking (HWT) test was used to gauge the rutting and moisture resistance. The test result shows the aramid fiber reinforced mixes exhibit satisfactory resistance to rutting and moisture damage.

Besides, Takaikaew et al. (2021) have proven that asphalt mixture with polyolefin-aramid fibers has lower rutting depth compared to conventional asphalt mixture. From the laboratory mix, the fiber-reinforced mixture has 30% lower rutting depth than the conventional mixture. The mix of plant also shows the fiber-reinforced mixture has a 40% lower rutting depth than conventional mixture. This highlighted the potential use of fibers to reduce rutting and persistent deformation caused by heavy traffic loads.

2.4 Mechanical performance of fibers in hot mix asphalt

Fibers are natural or synthetic substances used in the production of textiles and paper, as well as impregnated in products like cement and asphalt mixes. Fibers in HMA serve as reinforcement. Composites' strength, thermal stability, electrical conductivity, and frictional properties are all enhanced by fibrous reinforcement (Carlos et al, 2019). Engineers always combatting the problems in roads such as permanent deformation, fatigue cracking, and raveling. Polymers, anti-stripping agents, crumb rubber, sulphur, asbestos, roofing shingles, slag, and fly ash are among the most commonly used materials for this. Fibers in asphalt mixes are gaining popularity because they act as a reinforcement, increasing the material's ductility and tensile strength owing to improved aggregate interlocking. The interconnection between aggregates and fibers provides additional strain energy before cracking occurs. Thus, fibers are very useful in extending the service life of roads (Carlos et al., 2019).

An evaluation was done by Stanisław & Bartosz (2021) on the specimen's resistance to permanent deformation. The obtained results have demonstrated a definite increase in the resistance of mixtures with aramid-polyolefin fibers to permanent deformation, which is particularly significant for combinations used for wearing coarse. No matter the temperature range, the results revealed a considerable rise in rigidity modulus regardless of the temperature range. Results of trials have demonstrated that in cases when the existing pavement structure is reinforced, the thickness of the bituminous overlay may be reduced. The employment of aramid-polyolefin fibers in bituminous mixtures might enhance the functional characteristics of the pavement and be advantageous to investors.

2.5 Optimum bitumen content for ACWC 20 and ACBC28

Optimum binder content refers to the quantity of asphalt binder that balances several desirable mixed attributes for each combination of aggregate type, aggregate gradation, additive type, additive dose, and binder type (Hamzah et al., 2013). The average values that fulfill the sets of conditions for Marshall stability, Marshall flow, air voids, VMA, and VFB are used to calculate the optimal bitumen concentration of bituminous mixes (Ravindra et al., 2019).

An asphalt mixture of AC-20 and bitumen penetration grade 60/70 are used in the study by Ahmad et al. (2019). In the Marshall mix design, the optimal bitumen content (OBC) for AC-20 was obtained utilizing a trial approach with bitumen levels of 4.5 percent, 5.0 percent, 5.5 percent, and 6.0 percent, respectively. The maximum Marshall stability result was found at 5% bitumen concentration, which met the specifications of the National Highway System and international norms. By analyzing the volumetric properties of Marshall mix of different bitumen content, the conclusion of 5.5% as optimum bitumen content is made. (Ahmad et al., 2019)

For AC-28, the optimum bitumen content is given a range value between 3.5% to 5.5% from JKR specifications. To determine the optimum bitumen content of AC-28, the volumetric properties of AC-28 should comply with the value in table 4.3.5 from PWD specification. If any of the values do not comply with Table 4.3.5, the mix design procedure shall be repeated using different laboratory design mix aggregate gradation until all the design parameters are satisfied (JKR, 2008).

2.6 Effect of Pavement Thickness and Resilient Modulus to Pavement Life

Pavements are engineered structures that are used for parking lots, runways, and other purposes. The most widely used transportation worldwide is ground or surface transportation (Constructor, 2022). Thus, durable and reliable pavements should be built for the duration of their design life.

To design pavement with high design life, the factor of pavement thickness and resilient modulus cannot be negligible. Zara et al. (2022) have determined the impact of pavement thickness on pavement performance. From the study, it shows that as the pavement's thickness rose from 4 cm to 8 cm, the strain has significantly reduced. The study has shown that pavement thickness has a strong relationship with von Mises stress and strain. This result has proven that pavement life is affected by pavement thickness. The pavement life can be prolonged by increasing the pavement thickness to reduce the strain.

The purpose of Abu & Behiry (2012) study is to determine how changes in pavement modulus and axle load affect the total pavement life. The two main factors that regulate the balance between fatigue and rutting lives are base thickness and subgrade resilient modulus. The study result shows that the pavement strains are reduced as the modulus of the asphalt layer is increased. The research also shows the modulus of pavement can affect the fatigue and rutting life of the pavement. The result has indirectly shown that a higher modulus of pavement can provide longer service life.

Research shows pavement service life is affected by pavement thickness by utilized the FAARFIELD software. Increasing base layer thickness resulted in reducing HMA CDF for all aircraft models. Cummulative Damage Factor, CDF is the ratio of applied load repetition to allowable load repetition of failure. In short, the increase of pavement thickness will decrease the CDF, then the decreased CDF will increase the expected pavement life that generated from the FAARFIELD software (Ibrahim & Attia, 2019).

2.7 Summary

This chapter summarizes the application of asphalt mixture in airport pavement. Asphalt mixture is always utilized as construction materials for pavement because it can fulfill the requirements of different sectors of construction due to its flexibility. Hence asphalt mixes are widely used in the surfacing of runways and aircraft handling areas on a wide range of airfields.

This chapter also summarizes pavement failure. Pavement failure can be caused by many factors such as water intrusion, stress from heavy vehicles, expansion and contraction due to seasonal temperature variations, and sun exposure. Pavement failure occurs when an asphalt surface loses its original shape, generating material stress and causing subsequent problems. Appropriate maintenance, such as crack and asphalt sealing, is important and required to prevent cracks from spreading or growing.

Besides, polyolefin-aramid fiber is suitable to be used as an additive in pavement to enlengthen its service life. Fiber can increase rutting resistance, Marshall stability, durability, and so on for pavement strength. Investors should introduce polyolefin-aramid fibers in asphalt pavement to save the cost of pavement maintenance and rehabilitation practices. Laboratory works need to be done to verify and further improve the studies reviewed.

Lastly, some researchers have shown that pavement thickness and resilient modulus have a significant impact on pavement life. It is important to account for the factor of pavement thickness and resilient modulus in pavement design. FAARFIELD analysis is needed to be carried out to verify the relationship between pavement thickness and resilient modulus with the pavement life.

CHAPTER 3

METHODOLOGY

3.0 Introduction

The proposed experimental approaches to achieve the study objectives are discussed in this chapter. In terms of aggregates, binder, and mixture, the approaches are used to define the asphalt mixture that includes aramid and polypropylene as a modifier. The raw material used in this study is conventional 60/70 penetration grade asphalt binder, granite type aggregates, and hydrated lime as mineral filler. The aggregates used were sieved in accordance with the ACWC 20 and ACBC28 gradations. The hydrated lime used as mineral filler helps to reduce moisture-induced damages, thus controlling premature cracking. The addition of hydrated lime improves fatigue properties and minimizes cracking (National Lime Association, 2022). The 60/70 penetration grade bitumen is utilized as a binding agent due to its strong adhesion force and resistance to damage from water and oil spills. Eventually, the aramid and polyolefin are used as fiber modifications to improve the asphalt properties in terms of strength and durability.

3.1 Preparation of Raw Materials

A standard asphalt mixture consists of selected aggregates, binders, and mineral fillers, all of which are blended in a certain ratio. The asphalt mixture generated is supposed to be long-lasting and strong enough to handle severe traffic loads and uncertain weather and environmental condition. The preparation of raw materials, such as granite aggregates, asphalt binder, and hydrated lime as a mineral filler, is the important key step in this research.

3.1.1 Aggregates

Aggregates, also known as mineral aggregates, are non-reactive, hard minerals that serve as major load-bearing components. It normally makes approximately 95 percent of the asphalt mixture's weight and serves as the asphalt's principal load-bearing component.

The granite aggregates were gathered from the stockpile together with the quarry dust. Coarse aggregates which is higher than 2.36 or 3.35 mm were cleaned prior to the mixing process. The aggregates were placed in a specific container and placed in an oven for 24 hours at 110 Degrees Celsius (℃). After 24 hours, the aggregates were sieved into the required size ranges.

Once sieved, aggregates were batched accordingly as Figure 3.1. The batching process prepares the material according to the ACWC20 and ACBC28 gradations. The gradations are referring PLUS ACWC20 and PWD specification of ACBC28. The total mass of Marshall mixture will be 1.150kg. Hence, with a total mass of 1.150kg, the mass required for each aggregate size range was calculated as presented in Table 3.1 and Table 3.2.

Figure 3.1: Bags of aggregates according to gradation

Table 3.1: Aggregate Gradation of Asphaltic Concrete Wearing Course 20 (ACWC20) (PLUS Expressway Series 900)

B.S. Sieve Size	Percentage Passingby Weight	Median	Mix Design of AC 20	Mass of Aggregate	Cumulative Mass of Aggregate
		(%)	(%)	(g)	(g)
25 mm	100	100	0	0	0
20 mm	92 - 100	96	4	46	46
14 mm	70 - 84	77	19	218.5	264.5
10 mm	58 - 76	67	10	115	379.5
5 mm	40 - 56	48	19	218.5	598
2.36 mm	28 - 42	35	13	149.5	747.5
1.18 mm	20 - 32	26	9	103.5	851
600 µm	12 - 24	18	17	195.5	943
300 µm	7 - 17	10.5	7.5	86.25	1029.25
150 µm	5 - 13	9	1.5	17.25	1046.5
75 µm	5 - 9	7	2	23	1069.5
Mineral Filler			5	57.5	1127
Hydrated Lime			2	23	1150

Table 3.2: Aggregates Gradation of Asphaltic Concrete Binder Course 28 (ACBC28) (JKR, 2008)

B.S. Sieve Size	Percentage Passing by Weight	Median	Mix Design of AC 14	Mass of Aggregate	Cumulative Mass ff Aggregate
		(%)	(%)	(g)	(g)
28 mm	100	0	0	0	0
20 mm	72 - 90	81	19	218.5	218.5
14 mm	58 - 76	67	14	161	379.5
10 mm	48 - 64	56	11	126.5	506
5 mm	30- 46	38	29	333.5	713
3.35 mm	24 - 40	32	6	69	782
1.18 mm	14 - 28	21	11	126.5	908.5
425 µm	8 - 20	14	7	80.5	989
150 µm	4 - 10	7	7	80.5	1069.5
75 µm	3 - 7	5	2	23	1092.5
Mineral Filler			3	34.5	1127
Hydrated lime			2	23	1150