

Towards Sustainable Transportation Infrastructure

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Abstract: As the world's population continues to grow, urbanization expands, and transportation needs evolve, the demand for sustainable and efficient transportation infrastructure becomes more critical than ever. The interaction between traffic management and pavement sustainability plays a vital role in shaping the future of our cities. This book provides a comprehensive overview of traffic dynamics and pavement innovations focusing on sustainability.

The chapters in this volume are a collaborative effort from experts and researchers in transportation engineering, pavement materials, and urban planning. Throughout the chapters, readers will encounter various case studies and research findings that involve diverse facets of sustainable pavement practices and traffic engineering. Each chapter covers a specific topic, offering a blend of theoretical frameworks, laboratory works, and practical insights.

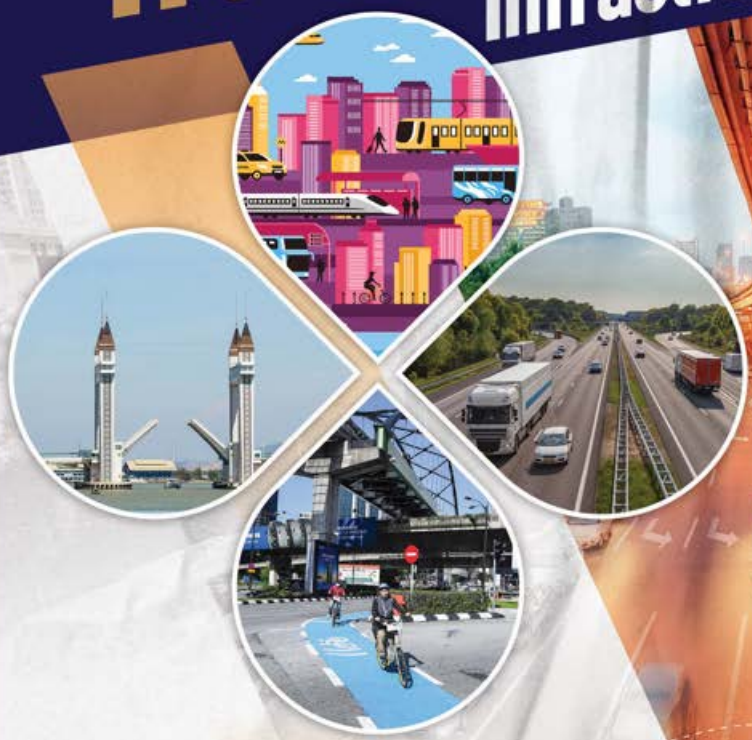
The structure of this volume has been designed with the initial sections focusing on sustainable pavement solutions with detailed research on alternative pavement materials and asphalt modification techniques. From novel approaches to material selection to integrating recycling and green technologies, these chapters provide a comprehensive overview of the evolving landscape of sustainable pavement design. Subsequent sections focus on the fundamental principles of traffic engineering, covering topics such as traffic flow analysis, accident analysis, and traffic modelling.

Ultimately, this book seeks to benefit a diverse audience, including practitioners, policymakers, researchers and students. We hope that the insights and knowledge shared within these chapters will serve as a source of inspiration in creating sustainable transportation infrastructure that harmonizes mobility, durability, and environmental responsibility.

Keywords: Traffic engineering, sustainable pavement, transportation infrastructure, alternative materials, green technology

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TOWARDS SUSTAINABLE TRANSPORTATION INFRASTRUCTURE



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PREFACE

As the world's population continues to grow, urbanization expands, and transportation needs evolve, the demand for sustainable and efficient transportation infrastructure becomes more critical than ever. The interaction between traffic management and pavement sustainability plays a vital role in shaping the future of our cities. This book provides a comprehensive overview of traffic dynamics and pavement innovations focusing on sustainability.

The chapters in this volume are a collaborative effort from experts and researchers in transportation engineering, pavement materials, and urban planning. Throughout the chapters, readers will encounter various case studies and research findings that involve diverse facets of sustainable pavement practices and traffic engineering. Each chapter covers a specific topic, offering a blend of theoretical frameworks, laboratory works, and practical insights.

The structure of this volume has been designed with the initial sections focusing on sustainable pavement solutions with detailed research on alternative pavement materials and asphalt modification techniques. From novel approaches to material selection to integrating recycling and green technologies, these chapters provide a comprehensive overview of the evolving landscape of sustainable pavement design. Subsequent sections focus on the fundamental principles of traffic engineering, covering topics such as traffic flow analysis, accident analysis, and traffic modelling.

Ultimately, this book seeks to benefit a diverse audience, including practitioners, policymakers, researchers and students. We hope that the insights and knowledge shared within these chapters will serve as a source of inspiration in creating sustainable transportation infrastructure that harmonizes mobility, durability, and environmental responsibility.

We extend our gratitude to the contributing authors whose expertise and dedication have enriched the contents of this book. Their collective efforts serve as a testament to the potential of collaboration in reshaping our urban transportation for the better.

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CHAPTER 1

SUSTAINABLE SUBGRADE MATERIAL: PALM OIL FLY ASH TREATED MARINE CLAY

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1.1 INTRODUCTION

The subgrade is a key structure in building the railways and highways. It is seen as the basis of road pavement. Subgrade supports the load transferred to the railway track or pavement through the subbase and road base. California Bearing Ratio (CBR) is crucial when assessing subgrade performance. CBR is an indirect measure of the shearing resistance of the material under controlled density and moisture conditions (Yashas, M. S. R., Harish, M. S. N., & Muralidhara, H. R., 2016). Building a subgrade on soft clay would create problems because of the likelihood of ravaging the pavement (Idrus, M. M. M., et. al., 2016). Soft subgrades in roadways are a recurrent issue in highway construction in many regions of the world (Fauzi, A., Fauzi, U. J., & Nazmi, W. M., 2013). According to ASSHTO, an unfavourable CBR value of the subgrade layer means a value less than 3% (Mohd Hisam, N. A., et. al., 2020). The attributes of the subgrade requirement must be attained regarding the CBR value. A minimum of 5% CBR is suggested for traffic volume related to the T1 through T5 Traffic Classes. Huge volume traffic (T4 and T5 Traffic Classes) entails a minimum subgrade strength of 12% (Hassan, A., et. al., 2013).

Marine clay is a soil mostly present in the lowlands, coastal corridors, offshore regions, and other areas of the earth (Mohammed Al-Bared, M. A., & Marto, A., 2017). This sediment is primarily accumulated along the coastal regions of Peninsular Malaysia (Rahman, Z. A., et. al., 2013). Marine clay is typically

2. The compaction test is performed for three treated specimens of one material against one control specimen. An increase in POFA decreased the MDD, indicating that POFA impacts marine clay density. The observation is alike that of marine clay mixed with lime material. Flocculation refers to the aggregation of particles, which, in this case, are clay particles that form clumps due to cation exchange, thereby resulting in higher volume, while a reduced dry density is observed. The reduction in density may be used to regulate the mix of materials to obtain the desired density. The specific gravities of POFA and marine clay are 2.02 and 2.60, respectively. Marine clay treated with POFA shows a different trend concerning moisture content, which increases as the POFA content increases. POFA addition to marine clay affects particle size, increasing voids between the particles. Consequently, higher moisture content fills the void; however, no significant increase in moisture is detected.
3. This study aims to ascertain the effects of POFA addition on the CBR value of marine clay and its use as an appropriate subgrade material. Based on the Malaysian Public Works Department, the required CBR value for the design is 12%. In the context of this study, the CBR value varied between 14% and 17% as POFA content was increased. POFA possesses a CBR value of 18% and is suitable for use as a subgrade substance. The conclusion is that POFA addition to marine clay leads to different CBR values, which, if increased, leads to higher strength.

1.5 ACKNOWLEDGEMENT

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CHAPTER 2

SUSTAINABLE USE OF WASTE IN COLD MIX ASPHALT

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2.1 INTRODUCTION

Cold mix asphalt (CMA) is a term used to refer to asphalt mixtures produced at ambient temperature (Usman K.R., et. al., 2021). Its essential constituents are aggregates (coarse and fine), emulsified asphalt or bitumen emulsion, cement, and water. Mixing at ambient temperatures is facilitated by bitumen emulsions in the form of liquid, which reverts to the original binder and coats the aggregates upon mixing or compaction (Thives, L.P., & Ghisi, E., 2017). CMA evolved from the need for a cost-effective, environmentally friendly, and structurally viable mixture. Furthermore, CMA entails simple mixing equipment and techniques, is easy to set-up in remote locations, and poses no hazard to workers - zero fumes (Warid, M. N. M., et. al., 2014). CMA presents a viable alternative to hot mix asphalt (HMA) in terms of minimal energy requirement, zero fumes emission, and mixing at an ambient temperature either in-place or in a plant. However, CMA is somewhat inferior to HMA, especially in its resistance to moisture damage. CMA's adjudged weakness renders it for use as patching mixtures and on light-trafficked low-volume roads (Warid, M. N. M., et. al., 2014). Therefore, using cheaply available material to improve CMA's performance and make it a far cheaper and economically justifiable alternative to HMA is advantageous. This fact leads to exploring industrial by-products and waste materials used for CMA production.

2.2 DEVELOPMENT OF COLD MIX ASPHALT

Early use of CMA dates back to the beginning of the 20th century in France, Ireland, and Germany, later in the USA and UK in the form of grave emulsions – a mixture of uniformly graded crushed aggregates, water, and bitumen emulsions.

HMA mixtures. The sustainability of including waste materials depends on a deep understanding of their microstructural composition and compatibility characteristics when mixed with asphalt emulsions. Furthermore, developing a universal mix design and in-service quality control evaluation is vital for CMA waste inclusion.

In addition to performance measures, the safe waste application requires further processing before use and subsequent inclusion in CMA.

2.7 ACKNOWLEDGEMENT

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CHAPTER 3

STIFFNESS CHARACTERISTICS OF COLD MIX ASPHALT MIXTURES

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3.1 INTRODUCTION

Cold mix asphalt (CMA) is a mixture of unheated, carefully selected materials comprising aggregate, cement, water, and bitumen emulsion. CMAs are used as a backfilling mixture for utility-cut and, to a lesser extent, in base courses or wearing courses of low-trafficked pavements. It has recently gained popularity since its introduction in France, coupled with increased production and usage of 1.5 million and 2 million tonnes in France and Turkey, respectively (Gómez-Meijide, B., & Pérez, I., 2014). CMA's increased acceptance is not unconnected to the CMAs' ease of production, simplicity of tools for its production, and flexibility in handling. Additional desirability of CMA is versatility with different weather conditions, environmentally-friendliness, fewer fumes – thus, safer to workers, cost-effectiveness – can be mixed and laid on site, and ultimately less carbon footprint. CMA is preferred for pothole patching and pavement rehabilitation, especially in wet and temperate weather. Moreover, research advances in emulsion production, material synthesis, and advanced testing/quality control measures leading to higher quality CMA production increased this popularity.

Nevertheless, these successes and continuous improvement in CMA performance and application are hindered by the cracking of backfilled mixtures due to low stiffness associated with low-strength CMA. The premature degradation due to CMA cracking causes an unjustified rehabilitation cost due to many reworks of damaged roads, endangering motorist safety. Also, low CMA's stability and resilience under various traffic loading and wetting-drying conditions may quicken added deterioration.



Fig. 3.4: Indirect Tensile Stiffness Modulus test setup.

3.6 CONCLUSION

CMA mixtures' stiffness with 4.75 mm NMAS of 4994 MPa recorded more than double the maximum stiffness of HMA at 90 days, as reported; moreover, dense-graded mixtures have higher ITS values than coarser gradations (Shanbara H. K., Ruddock F., & Atherton W., 2018). Marshall's volumetric properties revealed that dense mixes also exhibit high void content. However, the void is still within acceptable limits set by the UK Highway and Utility Committee of 2-10%. Continuous improvement of CMA's stiffness and other performance measures is a niche area for further research. Future studies should explore sustainable/renewable materials like industrial by-products in CMA to amend the identified CMA deficiencies.

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CHAPTER 4

BOTTOM ASH AS AN ALTERNATIVE PAVEMENT CONSTRUCTION MATERIAL

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4.1 INTRODUCTION

An enormous amount of raw materials has been consumed to develop infrastructures worldwide. Consequently, natural resources are at an alarming stage of depletion. Industrialization generates a tremendous amount of by-products ending up in landfills. Industrial wastes such as slags and ashes have historically been treated as solid waste by dumping in landfills. However, sustainable construction technology diverts industrial waste from landfills into recyclable materials. These readily available products are efficiently used in place of conventional materials for constructing roads. These cost-effective materials are effective in limiting the energy used for mining and generating products coupled with reducing greenhouse gases (Abdullah, M. H. et, al., 2019). Thus, these materials would help preserve natural resources for future generations.

4.2 COAL COMBUSTION PRODUCTS (CCPs)

CCPs are the residual deposits left after coal burning in a power plant for electricity production. These products could be found in fly ash (FA), bottom ash (BA), boiler slag and flue gas desulphurisation. FA and BA are the core products that the construction industry can potentially use as raw materials. FA produced in the form of dust-like powder is carried up by the flue gases of the furnaces. The residue is termed boiler slag during the combustion in the wet boiler. Flue gas desulphurisation is generated due to the scrubbing action by removing sulphur from the air emissions (Abdullah, M. H. et, al.,

Some BA properties do not favour its use in HMA-wearing courses. However, recent research revealed that the performance of wearing course asphalt mixtures remains constant by replacing a portion of fine aggregate with BA. Therefore, BA can potentially be used as an alternative paving material to reduce pollution and conserve natural resources.

4.8 ACKNOWLEDGEMENT

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CHAPTER 5

EFFECT OF INCORPORATING RECLAIMED ASPHALT PAVEMENT (RAP) INTO BITUMINOUS MIXTURES ON THE RHEOLOGICAL PROPERTIES OF BITUMEN

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5.1 INTRODUCTION

Each roadway construction project is carefully planned with a specific lifespan in mind. According to the specifications outlined by the Public Works Department of Malaysia (JKR), roads in the country are designed to last approximately ten years. This predetermined timeframe has implications for the depletion of the nation's natural resources, particularly regarding the aggregates and bitumen required for road resurfacing. The consequence of adhering to this limited lifespan is that valuable natural resources are utilized inefficiently, leading to potential resource scarcity and environmental degradation due to excessive road waste disposal.

The conventional practice of replacing roads every decade accumulates road waste residues, often deposited into landfills. This disposal process squanders valuable materials and threatens the surrounding natural environment. In light of these concerns, a proactive approach has been adopted to counteract wastefulness. This approach involves exploring alternative measures, such as refurbishing existing pavement to restore its elasticity and functionality. Furthermore, repurposing these materials can also involve their integration into new asphalt pavements.

There has been a growing emphasis on sustainable construction practices and integrating green technologies into infrastructure development. A notable strategy in this regard is the utilization of reclaimed asphalt pavement (RAP).

5.5 CONCLUSION

This study has found that the asphalt binder in RAP is stiffer and harder since it has been used for a long time. It can be seen through the results of the properties of bitumen in fresh mixtures and RAP mixtures. The major finding is the performance of the binder in the fresh mixture and RAP mixture. From DSR results, it can be concluded that mixtures that contain 60% RAP with bitumen 60–70 PEN are the most suitable to be applied in practice. The result is then supported by the penetration index (PI) between -1 and +1.

Some recommendations suggested for further research were as follows:

1. An additional sample for extraction is needed to conduct the bitumen tests. Additional samples need to be taken for every sample, maybe 5 to 10 samples. This is necessary to obtain consistent and accurate results.
2. The number of tests to analyse the performance of bitumen should be increased, such as the Rolling Thin Film Oven (RTFO), Bending Beam Rheometer (BBR), and Rotational Viscometer (RV).
3. All the equipment in the laboratory has to be maintained and calibrated from time to time to maintain its effectiveness. More accurate results can be produced with extra care and precaution while conducting all tests.

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CHAPTER 6

IMPACT OF TRAFFIC OVERLOAD ALONG KUALA KRAI FEDERAL ROAD

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6.1 TRAFFIC OVERLOADING ISSUES

With the increase in infrastructure development, the creation of adequate road facilities plays a vital role in transportation planning within Malaysia (Fozi, M. B. M., et. al., 2019). At present, Malaysian road networks consist of three primary classes, which are tolled expressways (1,821 km), federal roads (17,793 km), and state roads (227,502.398 km), with a total of 189,800.100 km of mostly paved roads (Rahmat, N. A., et. al., 2019, February).

Pavements can be classified into two types based on their structural conditions, which are flexible or rigid pavements. In flexible pavements, traffic loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, which has less strength, acts like a flexible sheet (e.g., a bituminous road). On the contrary, rigid pavement transfers traffic loads directly to sub-grade soil by the flexural strength of the pavement, where the pavement works as one solid unit instead of a collection of grain-like structures (e.g. cement concrete roads) (Mathew, T. V., & Rao, K. K., 2006). A thorough review of many factors other than layering thickness, such as material and construction requirements, as well as quality control, is critical in designing any pavement because it ensures that the resulting pavement structure performs as expected (AASHTO Guide for Design of Pavement Structures, 1993).

6.4 CONCLUSION

From this study, several conclusions can be derived from the findings, which are:

- With the design equivalence factor of 3.0, the only class that exceeds the design equivalence factor is Class 4 vehicles, which is six times higher than the allowable equivalence factor. In contrast, Class 3 vehicles exceed the limit for secondary direction by a factor of 3.
- Due to the increasing value of the equivalent standard axle, the required calculated design thickness is higher than the existing pavement thickness by 19mm. However, based on the calculated design thickness based on the current equivalence factor (E.F.), the existing pavement requires an overlay of at least 96mm for the primary direction and 83mm for the secondary direction.
- The pavement service life for the primary direction is expected to be reduced by nearly eight years, whereas the pavement service life in the secondary direction is reduced by nearly seven years.

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CHAPTER 7

PROPERTIES OF VIRGIN ASPHALT BLENDED WITH WASTE ENGINE OIL AND ARTIFICIAL AGED ASPHALT BINDER

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7.1 INTRODUCTION

Asphalt is semi-solid and obtained from a distillation process from crude petroleum (Porto, M., et. al., 2022). It binds aggregate particles and has four important physical properties: durability, rheology, safety and purity. The pavement industry typically relies on these physical properties for good performance characterization. However, the asphalt on the road can last around ten years and needs some modification to be recycled to avoid illegal disposal. An asphalt will age and become stiff and brittle due to the changes in adhesivity and ductility. As a result, this asphalt becomes harder and will cause fatigue cracking that influences the pavement's service life and strength.

Meanwhile, the increase in energy costs and strong worldwide demand for petroleum has encouraged many parties to develop ideas and innovation to save natural resources (Ratiu, S., Benea, L., & Armioni, M., 2022). To save construction costs, using reclaimed asphalt pavement (RAP) has gained interest among road builders. However, RAP has the potential to become aged and hardened due to exposure to radiation, oxygen and ultraviolet (UV). RAP can also produce stiffer asphalt and cause workability problems if not modified (Kamaruddin, N. H. M., et. al., 2014), leading to poor adhesion and cohesion properties (Al-Saffar, Z. H., et. al., 2021). This is due to the ageing of virgin asphalt, which reduces the maltene/asphaltene ratio (Hussein, Z., et. al., 2020). Usually, ageing processes are divided into two stages: short and long-term ageing. In the study of (Borghi et al. Borghi, A., 2017), it was reported that the RAP binder shows high brittleness and sensitivity to cracking due to ageing when compared with virgin asphalt. The degree of ageing depends on many factors, such as temperature, air voids, the mixture's content, and

used as a rejuvenating agent compared to those obtained from heavy machinery.

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CHAPTER 8

EFFECTS OF BIO-OIL FROM OIL PALM EMPTY FRUIT BUNCH ON BINDER PROPERTIES

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8.1 INTRODUCTION

Since the last century, asphalt binder has been a significant pavement material. Asphalt pavement has been a major pavement construction compared to rigid pavement. The main reason is that asphalt pavement has the advantages such as less time to construct and repair. Besides that, asphalt pavement is also smoother and quieter for driving. There is a high demand for asphalt material every year due to the asphalt pavement industry. On the other hand, crude oil prices are influenced by the different demands of the different grades. The alternative bio-renewable binder is a better way to reduce the use of asphalt binder from crude oil, which was recently applied for the pavement of material derived from fossil fuels (Zhang, Z., et. al., 2022). Previous investigations showed that the lignin and modified lignin products can be potentially used in the asphalt industry (Girimath, S., & Singh, D., 2019). Many of these materials can generate bio-oils, such as microalgae, animal waste (Raouf, M. A. & Williams, C. R., 2010), corn stoves (Fini, E. H., et. al., 2012), urban yard waste, etc. Biomass (plants and other organic waste) is converted into sustainable, low-carbon products that could replace existing petroleum products. This bio-binder extruded from biomass is a renewable fuel source from bio-conversion that can be blended into conventional asphalt as a modified binder. Using bio-modified binders in asphalt pavements could also reduce mixing and compaction temperatures and the ageing and stiffening characteristics of the reclaimed asphalt pavements (RAPs) and virgin binders (Rahman, M.,

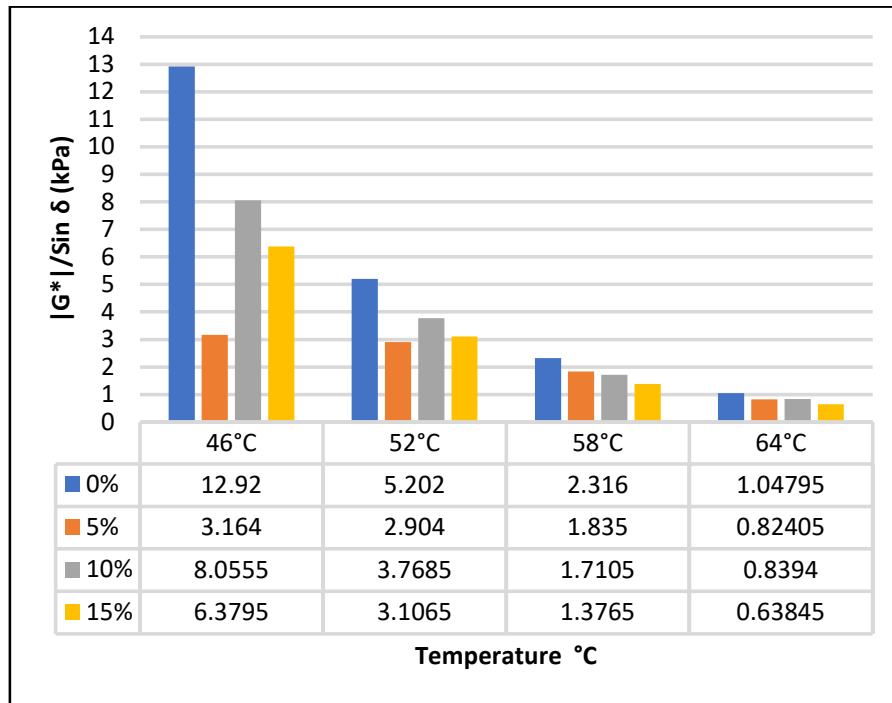


Fig.8.4: Rutting resistance of bio-oil modified binders at the failure temperature.

8.5 CONCLUSION

Overall, bio-binders offer an appealing alternative to modified asphalt binders due to their ability to improve some of the asphalt binder properties, such as wettability and low-temperature properties, as well as their advantages from an economic and environmental viewpoint. Through all the laboratory tests conducted, it can be concluded that the modified binder with the addition of 5% bio-oil can be used as modified asphalt. Although the modified asphalt of 5% bio-oil is softer than conventional, the modified binder provided the same properties.

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CHAPTER 9

EFFECT OF ASPHALT MIXTURE INCORPORATING TREATED PLASTIC AS ADDITIVE: MARSHALL PROPERTIES

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9.1 INTRODUCTION

Many severe distress, such as rutting and fatigue cracking due to increasing traffic load, higher traffic volume, and insufficient maintenance due to rapid development (Chen, X. & Huang, B., 2008; Ahmad, J., Rahman, M. A., & Hainin, M. R., 2011; Hainin, M. R., et. al., 2018; Selamat, N. A., et. al., 2019; Marwan, M., et. al., 2019). These issues have become the main concern since the 1970s to many researchers and road agencies to design and modify hot mix asphalt as the conventional mixtures to perform better and last longer (Zhu, J., Birgisson, B., & Kringos, N., 2014). A series of research has been conducted, and it has been found that adding additives is one possible approach that could modify and significantly improve the engineering value of asphalt mixtures (Azahar, W. N. A. W., et. al., 2017). The additive that is environmentally friendly and has an economical initial construction cost was the main criterion for producing a sustainable road mixture.

Plastic material is a plastomer type, such as high-density polyethylene (HDPE) and low-density polyethylene (LDPE), extensively used in manufacturing plastic bags, shampoo and many other plastic products. Massive production due to high consumer demand causes inappropriate disposal of a large amount of plastic waste in landfills and causes environmental problems. Consequently, policymakers and researchers were forced to find alternatives to overcome the issue, including converting the waste materials into road applications (Leng, Z., Padhan, R. K., & Sreeram, A., 2018; You, L., et. al., 2022; Ma, Y., et. al., 2021; Alemu, G. M., et. al., 2023; Heydari, S., et. al., 2021; Monticelli, R., et. al., 2023). It found that waste plastic as an additive improved the performance

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CHAPTER 10

PERFORMANCE OF ASPHALT CONCRETE INCORPORATING CUP LUMP MODIFIED BITUMEN

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10.1 INTRODUCTION

Excessive load and environmental demands have urged many researchers to modify conventional asphalt materials to overcome these issues, and polymer modification of bitumen (PMB) as one of the solutions (Airey, G. D., 2011). In addition, PMB could reduce the usage of fresh bitumen in asphalt mixtures where the depletion of bitumen as a non-renewable source also becomes a concern (Othman, Z., et. al., 2018). The significant advantages of utilizing PMB are less temperature susceptibility, higher elastic recovery, higher softening point, greater viscosity, and greater cohesive strength and ductility (Shaffie, E., et. al., 2016). PMB mixed with asphalt mixture is called polymer-modified asphalt (PMA). It exhibits higher strength with higher rutting and thermal cracking, lower fatigue damage, stripping and ageing resistance, creating a favourable material for infrastructure (Galooyak, S. S., et. al., 2010). The rheological properties of conventional bitumen will be modified by introducing cup lump as an elastomer type of additive into the mixture by mechanical mixing or chemical reaction (Zhu, J., Birgisson, B., & Krisgos, N., 2014).

The cup lump involved no manufacturing process; it is freshly coagulated rubber within the cup at the tree. The pavement with accurate percentages of rubber-modified bitumen may improve the binder and mix properties of the asphalt mixture, which should result in better field performance (Othman, Z., et. al., 2018). Rubberized asphalt mixtures using HMA have the potential advantages of greater resistance to permanent deformation and thermal cracking for greater durability (Bressi, S., et. al., 2019). Hence, further study in modified asphalt incorporating cup lump needs to be conducted.

it performs better in penetration, softening and flash point tests with 24.2, 11 and 15.7 %. It indicates that 5 % of CMB has higher resistance to permanent deformation cracking and less fire risk.

- When 5 % of CMB is mixed to produce asphalt, the stability and stiffness of 5 % of CMA improve by 12.2 and 0.9 %, respectively. Meanwhile, resilient modulus improves by 36 % and 13.1 % in resistance to low-temperature fatigue crack. In the dynamic creep analysis, 5 % of CMA improves rutting resistance with 23.1 %. Lastly, 5 % of CMA also improves the tensile strength of the mixture with 20.6 %.

In a nutshell, the modification of asphalt by 5 % of treated cum lump is not only has a significant effect on the performance of asphalt mixture and suitable to apply in warm climates country but also could reduce the usage of fresh bitumen in asphalt mixture with 5%.

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CHAPTER 11

DECISION TREE METHOD IN TRAFFIC ACCIDENT ANALYSIS

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11.1 INTRODUCTION

Road accidents have been one of the major issues in Malaysia highways for the past thirty-four years. The accident involved vehicles such as cars, lorries, buses, and motorcycles at a large traffic volume. Moreover, an estimated 1.2 million people are killed in road traffic crashes each year, and the number of injuries can be as high as 50 million (Zamri, N., Naim, S., & Abdullah, L., 2016). Many factors contribute to road traffic accidents, such as human factors (Goniewicz, K., et. al., 2016), vehicle factors (Suraji, A., & Tjahjono, N., 2012), and environmental factors (Treat, J., et. al., 1979; Ghazali, M., et. al., 2012; Jalilian, M. M., et. al., 2019).

An accident prediction model is progressively used to determine the causes of accidents (Chang, L. Y., & Wang, H. W., 2006; Abdullah, L., & Zamri, N., 2012; Ye, F., & Lord, D., 2014; Agbelie, B. R. D. K., 2016; Gianfranco, F., Soddu, S., & Fadda, P., 2018; Gaweesh, S. M., et. al., 2019; La Torre, F., et. al., 2019). Often, regression models are used, such as logistic regression (Chen, H., Cao, L., & Logan, D. B., 2012; Usman, T., Fu, L., & Miranda-Moreno, L. F., 2016), ordered logistic regression (Chen, F., Song, M., & Ma, X., 2019), generalised ordered logistic regression (Yasmin, S., et. al., 2014; Anarkooli, A. J., Hosseinpour, M., & Kardar, A., 2017), logit model (Chen, C., et. al., 2016; Dong, B., et. al., 2018), and ordered probit model (Garrido, R., et. al., 2014). The regression-based model

A bigger dataset is recommended to ensure the decision tree model's accuracy and better predictive power. Current developments in the decision tree model involve using sophisticated software such as Classification and Regression Tree (CART). This could enhance the iteration steps needed, especially for a bigger sample size.

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CHAPTER 12

ESTIMATION OF AVERAGE DAILY TRAFFIC FROM HOURLY VOLUME

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12.1 INTRODUCTION

Average Daily Traffic (ADT) is mainly used in traffic analysis. It is crucial to have an accurate ADT for the analysis as it will affect the design of roads in both urban and rural areas. One of the methods of obtaining ADT is collecting traffic data for one week. However, there are some conditions where such a long traffic count may not be reasonable. A Permanent Traffic Count is available on certain main roads to obtain AADT and ADT for a certain country. The AADT and ADT obtained then will be used in traffic studies, such as determining traffic control methods, generating traffic concept design for new development, and pavement thickness design for all roads with similar characteristics, which may cover most of the roads in the country. However, Permanent Traffic Count is very costly and requires continuous maintenance to ensure the accuracy of the data collected throughout the year. This has been a constraint for countries that could not afford it, for its high cost, lack of equipment, or lack of expertise in this field. Thus, other approaches are introduced by the US Federal Highway Administration (FHWA) to obtain this fundamental data, leading to the Short Duration Data Program. The Short Duration Data Program was introduced because continuous traffic counts could not be conducted. Both programs have similar objectives: obtaining traffic data for the studies, such as ADT, vehicle classification, travel speed and traffic pattern. In the Short Duration Data Program, the factoring or expansion factor approach adjusts the periodic count to obtain daily traffic volume. This expansion factor helps users to obtain Daily Traffic Volume or Average Daily Traffic from any hourly traffic volume or, in some cases, use Peak Hour Volume (PHV), thus allowing the traffic study to proceed. This approach is practiced in Malaysia to get the data whenever there are restrictions to conduct continuous traffic counts. The question that arises

12.6 CONCLUSION

It can be concluded that both methods of determining ADT from Hourly Expansion Factor (HEF) and Peak Hour Volume (PHV) can be used in practice. From the results, traffic engineers can obtain ADT for UTM, Skudai or any educational institution from only hourly traffic volume data. As the relationship between hourly volume and ADT for educational institutions is achieved, a long continuous traffic count does not have to be conducted to determine ADT. As long as there is a value of PHV, ADT can be determined for any educational institution in Malaysia by multiplying the PHV by 5.33. The HEF can be used for any roads in UTM with a similar traffic pattern of four gates. Thus, ADT can be obtained from the hourly traffic volume for any educational institution in Malaysia. It implies that the ADT for any road can be determined using the equation for PHF and HEF.

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CHAPTER 13

TRAFFIC IMPACT ASSESSMENT IN LAND USE CHANGE AND DEVELOPMENT PLANNING

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13.1 INTRODUCTION

In pursuing prosperous living, the world is experiencing rapid urbanisation with unceasing development, land use change, and road network expansion. Invariably, this will cause impacts to the traffic, as traffic demand increases to surpass capacity, traffic congestion, accidents, and other negative impacts on the environment. To control this phenomenon, a tool is needed to study and address those traffic impacts to ensure sustainable urban development so that road networks can meet traffic demand and will not degenerate in capacity (Lim, W. M., et. al., 2019). Traffic Impact Assessment (TIA) is practised worldwide; it is a systematic and scientific process to assess the impacts generated from the proposed development and to provide appropriate mitigation measures to maintain or improve road safety. TIA report provides stakeholders and practitioners, mainly developers, authorities, and engineers or consultants, a common platform to ensure land use developments are controlled in an orderly manner.

in three spectrums: macro, meso and micro. Hence, small, medium and large developments are assessed for effective implementation of TIA with the need for TIA within broader policies for urban development (Cooley, K., De Gruyter, C., & Delbosc, A., 2016). The case also called for new methods of funding for transportation facilities. Under the NSW Environmental Planning and Assessment Act 1979 section 94, provision of private involvement in shared funding is required and allocated for public transportation improvements within proposed development areas such as the “Green Travel Plan”.

13.6 CONCLUSION

TIA is necessary as a statutory submission for approval of development planning applications. Three case studies presented here illustrated how small developments such as a school upgrade in Australia, medium commercial area development in Malaysia, or a regional study at Dar es Salaam in Tanzania have impacted traffic conditions. If left uncontrolled with no improvements, these land use changes will cause traffic impacts to deteriorate the roads and intersection performance of existing and projected traffic conditions. This study also illustrates the importance of stakeholders in TIA implementation, emphasising the practice in national policy, guidelines, planning acts, and land or transport master plans. With time and experience, the practice will become more refined in studying the local traffic impacts more accurately for safer road networks and accessibility.

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CHAPTER 14

CALIBRATION AND VALIDATION OF MICROSIMULATION MODEL FOR HORIZONTAL CURVE

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14.1 INTRODUCTION

In today's world, the creation of computer models is not a new phenomenon. Many advanced computing models have been built during the last three decades to simulate varied traffic processes (Wang, Y., & Prevedouros, P.D., 1996). As the complexity of transportation networks has increased and more frequently been congested, simulation modelling as a valuable tool for deciding traffic operations has gained widespread recognition and acceptance. It is also possible to develop advanced applications for simulating traffic because modern computers are capable of such high-end performance, particularly in Malaysia, one of the countries worldwide that extensively uses traffic simulation.

In recent years, with the advent of various traffic models, the ability to apply computer simulation to evaluate traffic systems has indeed been efficiently proven (Bujang, Z., & Puan, O. C., 2017). This achievement was made possible by the fact that there are more traffic models than ever before. Nowadays, a broad range of infrastructures, such as intersections, interchanges, and corridors, have benefited from using traffic simulation models, which various stakeholders and professionals have utilised to assess the relative value of various design approaches (Azam, M., et. al., 2019). This is because findings can be acquired in a shorter amount of time that is also less risky and costly compared to actual deployment and testing in the field (Shaaban, K., & Radwan, E., 2005).

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CHAPTER 15

DRIVING SPEED ON APPROACHING AND LEAVING TANGENT OF HORIZONTAL CURVE

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15.1 INTRODUCTION

Road transportation is necessary to benefit the nation and the individual, particularly by improving access to the workplace, economic resources, educational facilities and health centres (Kamarudin, M. K., 2018). Even though road transportation has many advantages for the nation, it is also a major cause of accidents, which have consequences for drivers' safety, property loss, and traffic interruption. Accident-related injuries and fatalities are a significant public health issue, especially in developing countries, which are rapidly becoming motorised (Naghavi, M., Shahraz, S., & Bhalla, K., et. al., 2009). According to the World Health Organization, (2018), 93% of the world's fatalities on the roads occur in low- and middle-income countries, even though these countries have approximately 60% of the world's vehicles.

The causes of accidents are complex but broadly depend on drivers' behaviour. Driver behaviour involves the physical, psychological and emotional of the driver (Patel, H., & Gajghate, V., 2019). These variables can lead to improper overtaking manoeuvres, tail-gating while driving and over the speed limit (Ismail, A., Yi, G. S., & Mohd Zain, M. K. I., 2015). In traffic accident analysis, six factors—human factors, vehicle design, physical condition, traffic conditions, geometric aspects of the road, and weather conditions—are acknowledged as directly impacting traffic accidents (Chand, A., Jayesh, S., & Bhasi, A., 2021).

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Towards Sustainable Transportation Infrastructure

As the world's population continues to grow, urbanization expands, and transportation needs evolve, the demand for sustainable and efficient transportation infrastructure becomes more critical than ever. The interaction between traffic management and pavement sustainability plays a vital role in shaping the future of our cities. This book provides a comprehensive overview of traffic dynamics and pavement innovations focusing on sustainability.

The chapters in this volume are a collaborative effort from experts and researchers in transportation engineering, pavement materials, and urban planning. Throughout the chapters, readers will encounter various case studies and research findings that involve diverse facets of sustainable pavement practices and traffic engineering. Each chapter covers a specific topic, offering a blend of theoretical frameworks, laboratory works, and practical insights.

The structure of this volume has been designed with the initial sections focusing on sustainable pavement solutions with detailed research on alternative pavement materials and asphalt modification techniques. From novel approaches to material selection to integrating recycling and green technologies, these chapters provide a comprehensive overview of the evolving landscape of sustainable pavement design. Subsequent sections focus on the fundamental principles of traffic engineering, covering topics such as traffic flow analysis, accident analysis, and traffic modelling.

Ultimately, this book seeks to benefit a diverse audience, including practitioners, policymakers, researchers and students. We hope that the insights and knowledge shared within these chapters will serve as a source of inspiration in creating sustainable transportation infrastructure that harmonizes mobility, durability, and environmental responsibility.



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