

**UTILISATION OF RECLAIMED ASPHALT
PAVEMENT WITH WARM MIX ASPHALT AS
SUSTAINABLE PAVEMENT TECHNOLOGIES:
COMPREHENSIVE REVIEW AND
CHALLENGES**

SYAQIRAH BINTI NORGAN

**FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
2022**



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**THESIS SUBMITTED IN PARTIAL FULILLMENT
OF THE REQUIREMENT FOR THE DEGREE OF
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2022**



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DECLARATION

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CERTIFICATION

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ABSTRACT

Road construction is one of the most significant projects all over the world. However, the high temperature required when producing asphalt mixture could affect the environment. Therefore, new technologies of warm mix asphalt (WMA) incorporated with reclaimed asphalt pavement (RAP) are introduced as solutions to the concern. Previous research indicated that this technology showed good performance and promoted environmental, economic, and social sustainability. Thus, this study aims to analyze and review RAP-WMA technologies. Specifically, each performance and sustainability will be categorized and analyzed. Further, identified the challenges in implementation, particularly in Sabah, through a questionnaire also done. Based on the literature, the structured review in tables and figures is used to categorize each RAP-WMA performance and determine the sustainability of RAP-WMA technologies in terms of environment, economy, and society. Meanwhile, questionnaires were distributed online to road construction companies in Sabah. As a result of the review, 18 articles reported on the RAP-WMA performances. The results shows that the RAP-WMA performed as well as or better than the conventional asphalt mixture from the literature. Furthermore, 15 articles reported on the RAP-WMA sustainability, where it demonstrates sustainability in a variety of ways, including lower greenhouse gas emissions, lower production costs, and a better working environment when used. Whereas 36 people were surveyed, the data were analyzed using SPSS software and computerized-based Microsoft Excel. The result reveals that using this technology in Sabah is impacted by cultural, financial, and technical barriers. According to the respondent's assessments of the challenges using RAP-WMA technologies in Sabah, the biggest obstacle is a technical one (38%). Therefore, raising awareness, and introducing RAP-WMA technologies to clients is needed.



ABSTRAK

PENGGUNAAN TURAPAN ASPAL YANG DIKITAR SEMULA DENGAN ASPAL CAMPURAN SUAM SEBAGAI TEKNOLOGI TURAPAN LESTARI

Pembinaan jalan raya adalah salah satu projek yang paling penting di seluruh dunia. Walau bagaimanapun, suhu tinggi yang diperlukan semasa menghasilkan campuran asfalt boleh menjejaskan alam sekitar. Oleh itu, teknologi baharu asfalt campuran hangat (WMA) yang digabungkan dengan turapan asfalt tebus guna (RAP) diperkenalkan sebagai penyelesaian kepada kebimbangan itu. Kajian terdahulu menunjukkan bahawa teknologi ini menunjukkan prestasi yang baik dan menggalakkan kelestarian alam sekitar, ekonomi dan sosial. Justeru, kajian ini bertujuan untuk menganalisis dan menyemak teknologi RAP-WMA. Secara khusus, setiap prestasi dan kemampuan akan dikategorikan dan dianalisis. Seterusnya, mengenal pasti cabaran dalam pelaksanaan, khususnya di Sabah, melalui soal selidik yang turut dilakukan. Berdasarkan literatur, semakan berstruktur dalam jadual dan rajah digunakan untuk mengkategorikan setiap prestasi RAP-WMA dan menentukan kemampuan teknologi RAP-WMA dari segi persekitaran, ekonomi dan masyarakat. Sementara itu, borang soal selidik telah diedarkan secara dalam talian kepada syarikat pembinaan jalan raya di Sabah. Hasil daripada semakan, 18 artikel melaporkan tentang persembahan RAP-WMA. Keputusan menunjukkan bahawa RAP-WMA berprestasi sebaik atau lebih baik daripada campuran asfalt konvensional daripada literatur. Tambahan pula, 15 artikel melaporkan tentang kemampuan RAP-WMA, di mana ia menunjukkan kemampuan dalam pelbagai cara, termasuk pelepasan gas rumah hijau yang lebih rendah, kos pengeluaran yang lebih rendah dan persekitaran kerja yang lebih baik apabila digunakan. Manakala 36 orang telah ditinjau, data dianalisis menggunakan perisian SPSS dan Microsoft Excel. Hasilnya menunjukkan bahawa penggunaan teknologi ini di Sabah dipengaruhi oleh halangan budaya, kewangan dan teknikal. Menurut penilaian responden terhadap cabaran menggunakan teknologi RAP-WMA di Sabah, halangan terbesar ialah halangan teknikal (38%). Oleh itu, usaha untuk meningkatkan kesedaran dan memperkenalkan teknologi RAP-WMA kepada pelanggan perlu dilaksanakan.

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LIST OF NOTATION SYMBOLS

- % - Percentage
- °c - Degree Celsius
- < - Less than
- & - And
- ↑ - Increase
- ↓ - Decrease
- ↔ - Mixed
- - No reported performed

LIST OF ABBREVIATION

| | | |
|-----------------------|---|---|
| CEI | - | Compaction energy index |
| CO | - | Carbon Monoxide |
| CO₂ | - | Carbon Dioxide |
| CSR | - | Composite Schedule Rates |
| E.g., | - | Example |
| et al. | - | And Other |
| FHWA | - | Federal Highway Administration |
| FYP | - | Final Year Project |
| GHG | - | Greenhouse Gas |
| HAP | - | hazardous air pollutants |
| HMA | - | Hot Mix Asphalt |
| ITS | - | Indirect Tensile Strength |
| LCA | - | Life Cycle Assessment |
| LCCA | - | Life Cycle Cost Assessment |
| NCAT | - | National Center for Asphalt Technology |
| NCHRP | - | National Cooperative Highway Research Program |
| NO_x | - | Nitrogen Oxide |

- RAP** - Reclaimed Asphalt Pavement
- Ras** - Recycled Agents
- SCB** - Semi-circular Bending
- SDGS** - Sustainable Growth Goals
- SHRP** - Strategic Highway Research Program
- SO₂** - Sulfur Dioxide
- SPSS** - Statistical Package for Social Science
- TPM** - Total Particulate Matter
- TSRST** - Thermal Pressure Resistance Specimen Test
- UAE** - United Arab Emirates
- UTCT** - Uniaxial Tension Compression Test
- WMA** - Warm Mix Asphalt



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CHAPTER 1

INTRODUCTION

1.1 Overview

Reclaimed asphalt pavement (RAP) is one of the recycled materials from the waste construction. Basically, reclaimed asphalt is the old asphalt obtained from the road surfaces deteriorates and ongoing damages by the traffic where it is removed and disposed in landfills (Wrobel et al., 2021). The use of RAP as a replacement for a fraction of natural aggregates in the construction can be an alternative way to reduce the environmental problem (Yousefi et al., 2021). However, due to the change in properties of the RAP material, the RAP could not be treated like the virgin material for the new asphalt pavement. Thus, mixing RAP with warm mix asphalt (RAP-WMA) can be a sustainable technology that improve the performance of the new asphalt pavement.

Warm mix asphalt technology is the technologies of low temperature in producing asphalt. Since the traditional production of asphalt using hot mix asphalt emits harmful greenhouse gasses, many countries started experimenting on WMA technology to reduce the environmental pollution. Apart from that, using the hot mix asphalt (HMA) usually causes the RAP materials to experience secondary aging and results in poor mechanical performances. Other than that, cause of ageing also is due to the reaction of asphalt components with oxygen, which occurs mainly during the production of asphalt mixes and leads to irreversible chemical changes in the binder (Wróbel et al., 2021). Thus, using WMA is more beneficial due to lower production temperature (Yousefi et al., 2021).



The RAP study has been varying to assess its properties and performances. Most researchers found that the RAP properties improve when additional material such as rejuvenator, recycle agent and technologies used to produce the asphalt is suitable. Apparently, all research on RAP-WMA technologies only happens in overseas, while, in Malaysia there are still a lack of research found due to the lack of utilization of RAP-WMA technologies and awareness in sustainable highway (Bujang et al., 2018). Due to this fact, comprehensive review of RAP-WMA technologies will be studied.

1.2 Definition

To gain a better idea of the overall study, the study defines a few terms. The term was derived primarily from dictionaries and articles. The definition of the word is as follows:

Challenges: A challenge is something that requires significant mental or physical effort to complete successfully, or the situation in which such effort is required (Source: Cambridge English Dictionary, 2018).

Technology: A human-created system that uses knowledge and organization to produce objects and techniques for achieving specific goals (Carroll, 2017)

Sustainable: The ability to continuously maintain or support a process over time (Mollenkamp, 2022)

Utilization : Utilization is the act of using something in an effective way. (Source: Cambridge English Dictionary, 2018).

Recycling : Process of converting waste materials into reusable things to reduce waste of potentially useful materials, consumption of fresh raw materials, energy consumption by reducing the requirement

for conventional garbage disposal, and greenhouse gas emissions (Agir, 2016)

1.3 Background of Study

Road construction, is one of the biggest projects all over the world. The road surfaces usually construct using the mixture of bitumen and aggregate which is called asphalt pavement and consist of few layers producing the road. However, the use of virgin material to construct the new road could affect the environment. The road construction using virgin or raw material contribute to the large carbon dioxide (CO₂) emission. According to the case study in United Arab Emirates, UEA (2021), where most of their road construction are using virgin material for example along 21, 673 km paved road in Abu Dhabi, the UAE become one of the largest per capita emissions globally. As an alternative way to reduce the environmental impact, Asphalt recycling is one of the asphalt pavement rehab procedures (Yousefi et al., 2021). Despite being the environmentally friendly material, it is also economically beneficial in terms of saving on mine aggregate and asphalt as well as avoiding costly waste disposal and storage (Wrobel et al., 2021). The used of RAP is not limited as sub-base layer material but it also can be used as the shoulders hardening, ground road strengthening and more.

Warm mix asphalt (WMA) and reclaimed asphalt pavement (RAP) are two frequently used technologies in the industry. The RAP-WMA mixture produces a long-lasting pavement structure that performs nearly as well as standard asphalt pavement (Guo et al., 2020). Furthermore, it improves the road pavement's performance by reducing the requirement for compaction because WMA has higher workability due to the improved aggregate covering (Gungat et al., 2020). Various researchers have reported varying results regarding the performance of WMA technologies, which could be attributed to the type of WMA technology, the amount of WMA additive, the number of other materials/additives (e.g., recycled materials) in WMA, the temperature and time-dependent characteristics of the binder, and the

various tests used to evaluate WMA binders and mixtures (Behnood, 2020). It is critical to comprehend each RAP-WMA technology's condition and performance in relation to its category.

The main goal of this study is to provide comprehensive review on the utilization of RAP-WMA technology as sustainable pavement technology based on existing literature review. From the existing literature review, the RAP-WMA performances is categorized accordingly, the sustainability of RAP-WMA also analyze in terms of environment, economic and social sustainability, and determine the challenges behind using RAP-WMA technology in road applications specifically in Sabah.

1.4 Problem Statement

The utilization of RAP-WMA mixture can be sustainable pavement technologies in the future because of its benefits, mainly on providing environmentally friendly and reducing waste material and disposal storage. Much previous research has been discussed on the effectiveness of the utilization of reclaimed asphalt pavement with warm-mix asphalt technologies, such as by Gungat et al. (2020); Liu et al. (2020); Yousefi et al. (2021); Liu et al. (2017). They claimed that this utilization of RAP-WMA can reduce the environmental problem and can be one of the waste management systems.

Although various studies have been published, the industry is still reluctant to use the RAP-WMA technologies. For example, in Malaysia, there are hard to find the use of these RAP-WMA technologies. In addition, there are just a few review papers on the WMA-RAP mixture performance. One of the barriers to use of high RAP asphalt mixtures is a lack of confidence in their performance. Moreover, due to many various ways for creating WMA, thus, it's impossible to generalise the qualities. Hence, it is advised to categorize each survey based on WMA technology and evaluating the WMA-RAP mix correspondingly in their prior study for better understanding.