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Cold Mix Asphalt as Permanent Road Resurfacing Solution: A Short Review Aligned with the Sustainable Development Goal (SDG) 7

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Abstract

Surface damage to pavement is frequently caused by elements including traffic volume, moisture content, and problems with the state of the pavement, such as potholes, ravelling, or permanent deformation. Potholes are a prevalent issue on paved surfaces that, if ignored, can weaken the pavement and cause damage to the underlying materials, which can lead to wear and fracture from the affected asphalt surface's lack of support. This study aimed to conduct a comprehensive review of the potential of Cold Mix Asphalt (CMA) as a sustainable, environmentally friendly, and economically advantageous solution for permanent road resurfacing. The research consolidated information from sources on Science Direct, Scopus, and Web of Science that focused on the use of CMA for resurfacing purposes. Furthermore, the analysis sought to evaluate the efforts to promote CMA as a more preferable choice for addressing road deterioration. Ultimately, this study aimed to ascertain whether CMA holds promise as a long-term solution for road resurfacing. This study also supports the SDG 7 objective to ensure access to affordable, reliable, sustainable and modern energy by promoting the usage of cold mix asphalt as an option for permanent road resurfacing. Surface damage to pavement, caused by factors such as high traffic volume, moisture content, and structural issues like potholes, ravelling, or permanent deformation, remains a significant challenge for infrastructure maintenance. Among these issues, potholes are particularly pervasive and, if neglected, can compromise the pavement's integrity, leading to further deterioration of the underlying materials and escalating repair costs. Addressing these problems requires innovative and sustainable solutions that balance environmental and economic considerations.

Keywords*:* Cold Mix Asphalt, Permanent Road Resurfacing, Additive for Cold Mix Asphalt, Road Construction, Sustainable Development Goal

Introduction

This study is motivated by the need for a reliable and long-lasting method to mitigate road deterioration while minimizing environmental impact. It coordinates well with Sustainable Development Goal (SDG) 7 which stresses on providing access to affordable, reliable, sustainable and modern energy for all. Road construction plays a crucial role in Malaysia's economic and social advancement, constituting a dynamic aspect of the civil sector that undergoes continuous upgrades and developments. This process often leads to the emergence of new technologies that prioritize functionality, cost-effectiveness, sustainability, and ecological friendliness which really aligns with the SDG 9. Malaysia's road infrastructure, predominantly composed of paved roads, faces an ongoing demand for maintenance and improvement, with roughly 80% of these roads affected. This is attributed to factors such as heavy traffic, frequent intense rainfall, flooding, inadequate maintenance as well as shortcomings in both design and construction approaches.

Several persistent and unresolved issues have sparked heated discussions and complaints among the populace. Among these, potholes stand out as a recurring problem that, if left unaddressed, can lead to pavement fatigue and breakage. Over time, strategies for mitigating potholes have evolved alongside technological advancements. Two prominent approaches to addressing this issue involve Cold Mix Asphalt (CMA) and Hot Mix Asphalt (HMA). CMA is typically employed for smaller defects due to its simplicity and efficiency, while HMA is utilized for larger areas given its reliance on machinery during production. In terms of cost, CMA presents a more budget-friendly option when compared to HMA. Nonetheless, it's important to note that HMA offers a permanent solution, whereas CMA serves as a temporary alternative.

Despite CMA's recognition for maintenance purposes, its implementation has yet to be deemed the optimal long-term solution, as certain improvements are still necessary before it can be considered as such. An inconvenience associated with CMA is its extended curing period, during which the asphalt takes several weeks to attain its ultimate strength. In contrast to HMA (Hot Mix Asphalt), CMA also exhibits lower mechanical performance and a higher degree of porosity, rendering it unsuitable for immediate deployment. Another limitation of CMA lies in its incapacity to withstand pressure immediately after installation. This is due to the need for moisture content in the mixture to evaporate, allowing for proper compaction. Consequently, this makes it impractical, necessitating road usage restrictions.

However, due to the lack of performance studies, deficiencies in grading systems and standardization, as well as perceptions of its inferior performance as a structural layer, CMA has received limited attention. Nevertheless, there should be a concerted effort to prioritize the advancement of sustainable and environmentally friendly technologies like cold mix technology in light of growing environmental needs. The utilization of CMA as patching materials can be characterized as efficient, time-saving, and economical. This will help in contributing a great positive change to the environment as well as the community as a whole.

Methods of Review

This paper will describe engineering parameters of CMA through reviewing its advantages, disadvantages and the strategies to make CMA better by performance enhancement. 43 articles were chosen to prioritize pertinent research, underwent in-depth assessment. The selected publications shed light on key advancements, barriers, and the potential of CMA, aiming to offer resource for sustainable pavement materials research.

Result and Analysis

Cold Mix Asphalt

Traditionally, pavement resurfacing has been both costly and time-consuming. However, with technological advancements, methods for addressing issues like potholes have evolved. These methods often require a significant amount of labour and workforce. Consequently, CMA offers a more expedient and straightforward approach compared to HMA. Unlike HMA, which requires higher temperatures for bonding, CMA binds its aggregate and residual asphalt at ambient temperature, leading to reduced energy consumption. Thus, the utilization of CMA as patching materials is deemed efficient, time-saving, and cost-effective (Huang et al., 2020). In contrast to HMA and Warm Mix Asphalt (WMA), it can also be made in small batch. It is inevitable that the materials used must be stored and are accessible at all times when needed since the never-ending demands to repair pavement defects frequently require certain quantities and are done at certain times. Nevertheless, HMA and WMA are unsuitable for repairs since they cannot be made or kept in small quantities (Diaz, 2016).

The term "cold mix" refers to a mixture of aggregate and bitumen emulsion. The bitumen is emulsified in water as part of the CMA operations, and when the mixture is compacted or mixed, it breaks, coating the aggregate and creating the cold mix asphalt mixture. As the asphalt is applied to the surface, the water progressively evaporates, strengthening the asphalt mixture. In comparison to HMA and WMA, CMA is proven to be more affordable, user-friendly, and environmentally benign.

CMA is frequently utilised for external projects that aren't subject to a lot of traffic or load. As the name implies, cold mixes are made with unheated aggregate and bitumen emulsion, making them a good option for reducing pollution since no heating process is needed. The ultimate goal is to create high-quality asphalt in a comfortable environment as stated by Redelius et al., (2012) that the best method to produce high-quality asphalt is CMA made from bitumen emulsions.

The Advantages of Cold Mix Asphalt

Cold Mix Asphalt (CMA) has been the subject of numerous studies highlighting its myriad benefits. This section delves into the potential that CMA brings to the industry, focusing on its environmental and economic aspects. The forthcoming discussion will outline these advantages in the following manner:

Beneficial for Green Sustainable Environmental, Social and Economic Perspective

Rather than utilizing hot bitumen, CMA can be manufactured at ambient temperature by employing bitumen emulsion, thereby reducing the energy required in the production process. According to Le Bouteiller (2010), producing similar cold-mixed asphalt using an emulsion only required 13% of the energy needed to manufacture hot-mixed asphalt at 160 °C. The CMA was able to be created ahead of the works while the hot mix plant was cold, freeing the plant to produce regular hot mix throughout the installation. Khoker and Kazal (2015) supported this by stating that the access to CMA requires no waiting time and need no heat. CMA remains usable as long as it is not allowed to dry out by evaporation or the moisture is extruded during compaction (Day et al., 2019).

The advantages of this approach are widely acknowledged: it eliminates the need for heating the mixture, reduces transportation and raw material usage, ultimately saving time, money, and reducing CO2 emissions (Orosa, Medina, et al., 2022). As a result of the decreased gasoline use, Jain and Singh (2020) noted the reduction in cost. In addition to being ecologically friendly, it also cuts down on labour hours. According to Ling and Bahia (2018), utilising CMA shortens the time required for transportation and mixture placement.

Nonetheless, CMAs have been employed in the majority of countries for a variety of asphalt surface treatments since they are economically advantageous, environmentally friendly when made with bitumen emulsions, and sustainable (Usman et al., 2021; Gandi et al., 2019; Hasanuzzaman et al., 2017). According to Offenbacker et al., (2020), more money is needed to preserve a pavement in order to achieve a satisfactory level of performance. Cost evaluation must always be carried out and taken into account to ensure that performance may be compared with benefits to society and production costs. Offenbacker further claims that the costs associated with producing asphalt may be broken down into three categories: construction, energy, and environmental costs. As a result, CMA is increasingly being used for pothole filling in the pavement sector since it uses less energy, has lower startup costs, emits less greenhouse gases, and is more environmentally friendly than HMA (Yang et al., 2021; Bi et al., 2020). As a result, Boateng et al. (2021), citing Ling et al. (2016), concluded in their research that cold-mixed cold-laid patching mixtures are widely favoured for maintenance purposes and represent promising alternatives for various pavement applications in international contexts. The creation of flexible pavement material using CMA, a low carbon manufacturing method, has shown to be very promising from both an economic and environmental standpoint. It enables the creation of mixtures at room temperature without heating massive quantities of bitumen and aggregates, reducing CO2 emissions and conserving energy. As it offers adequate performance in addition to energy-saving and environmental goals, it is also a crucial approach for paving. Although CMA is produced and applied at lower ambient temperatures than HMA, it uses less energy to reduce bitumen viscosity. CMA considerably lowers manufacturing emissions and odours, improving the working conditions for operators and production employees (Shanbara et al., 2021).

With its mechanical strength growing over time as it cures, cold mix asphalt is typically regarded as a sustainable material (Li et al., 2020). The use of cement significantly increased the mechanical performance of CMA. Additionally, CMA has a great degree of durability, according to Lundberg et al. The observed road surfaces were in good shape despite having a high void content in the asphalt, and even 15 years after paving, there were hardly any cracks to be seen (Sarsam, 2021).

In his study, Kazal (2015) noted that CMA uses an environmentally benign method with no pollution and provides ready-to-use ingredients without heating or preparation close to the roadside. Most importantly, it is easier to use and more functional. Also, it is labor friendly because there are no occupational hazards for the workers. Unskilled workers can benefit from this by getting more employment opportunities. Furthermore, CMA can be laid 4-5 times faster than HMA and can construct 1 km of pavement in 3–4 days with the right manpower and support as it also works in humid and wet weather conditions. In addition to being quick and simple to prepare, it also doesn't use a lot of energy (Arshad et al., 2018), confirming its claim to be both environmentally and energy-friendly. As it doesn't produce any pollutants or release any dangerous gases, it is regarded as an environmentally benign strategy.

The Disadvantages of Cold Mix Asphalt

Despite its excellent performance, CMA still has its own flaws. The amount of CMA generated is still relatively small as compared to the overall amount of asphalt produced globally, despite its enormous energy savings. This is mainly because CMA and HMA behave differently; CMA is brittle right once after laying and needs time to cure before becoming fully stiff. However, the lack of CMA standardization has also slowed its advancement, despite several notable instances of its widespread acceptance (Day et al., 2019).

While CMA performs similarly to HMA in terms of effectiveness, it is frequently viewed as being less preferred. The fundamental issue with CMA is that, in comparison to HMA, it is not as strong. According to Jain and Singh (2020), CMA typically falls short of the crucial requirements for strength and stability. CMA is discovered to have a lower Marshall Stability than HMA. While being 4-5 times faster than HMA, the CMA approach has not yet gained widespread acceptance and use.

In Boateng et al.'s (2021) research area concerning bituminous pavement maintenance, premature patch failures, including those in pothole and partial-depth repairs using CMA, are prevalent and pose a significant challenge. These failures necessitate repeated patching despite limited maintenance budgets and frequent traffic disruptions. The most commonly reported failures of CMA patches in the region include disintegration, shoving, and dishing. These failure scenarios typically indicate weaknesses in both binder and aggregate functionality, often stemming from a compromised aggregate skeletal structure with inadequate interlock and load-bearing capacity, resulting in patches lacking stiffness and stability. The use of CMAs still has some drawbacks, including weak early strength, poor material compatibility, and poor adhesion that frequently led to excessive void levels (Raschia et al., 2021).

The Performance Enhancement of Cold Mix Asphalt

In a study by Kazal, (2015) additives are added to cold mix asphalt. This is done to improve the performance of the production. There are two ways to add additives: either during the cold mix production process with the aggregate, or before the cold mix production process with the bitumen emulsion. The mechanical qualities of bituminous pavements can be influenced by a variety of factors, including mix density and void content, bitumen binder grade and its rheological properties, curing period, aggregate properties, and the kind and quantity of additives (Lu et al., 2021; Tian et al., 2020b; Du, 2018).

Li et al., (2020) quoting Cross et al., (1999); Niazi et al., (2009); Nageim et al., (2012); Nassar et al., (2016); Yan et al., (2017); Wang et al., (2018) stated additives including Portland cement, fly ash, and lime are commonly utilized in bitumen emulsion-based asphalt mixtures to enhance their mechanical qualities. This statement is supported by Arshad et al., (2018) that quoted additives including cement, lime, and fly ash were utilized to change the cold mix's characteristics and improve its performance. The majority of studies advised adopting cement as an ingredient because it enhanced the mix's characteristics and produced extremely good results (Dash, 2013).

Cement

According to Okoroafor et al., (2017), cement is a calcareous and argillaceous substance. It transforms into a glue-like liquid when combined with water, which binds aggregates like sand, gravel, and stones. Chemical reaction causes it to thicken and harden. Oruc et al., conducted studies to assess the mechanical qualities of an asphalt mixture with cement replacing mineral filler in a percentage increase from 0 to 6%. A structural pavement layer may be created using cement-modified asphalt emulsion mixes, according to this test. Additionally, they demonstrate that the early strength was increased by adding 1 to 2% of rapid setting cement. Dep et al. conducted a study comparing mixtures treated with cement to untreated mixtures, revealing that cement-treated mixes exhibit greater stiffness and strength. Furthermore, the resistance to moisture of cement-treated mixes is notably stronger, ranging from 80.51% to 95%.

When Leng, et al., (2017) examined the effects of various cement contents on the characteristics of CMA, they discovered that both the early-age strength and the long-term performance were enhanced. Moreover, it was found that the moisture loss rate in CMA decreased as cement content increased, which is primarily due to cement hydration (Fang et al., 2016). This demonstrates that the cement could increase the initial curing rate of CMA as well as the long-term mechanical performance (Li et al., 2020). Marshall test results by Kazal, (2015) concluded that cold mixes with cement as an ingredient fared the best of all the mixes in every category when compared to dense grade mixes. Also, it was discovered that specimens with cement outperformed specimens without cement in terms of rutting performance. The outcomes also demonstrated that 2% Portland cement accelerated the mixes' curing times and considerably enhanced their performance. As the conclusion CMA is a practical substitute for hot mix asphalt when used as a pavement surfacing material according to Arshad et al., (2018).

Lime

In contrast to granite and granite fillers, limestone and limestone filler have a considerable impact on hardness, according to a study by Wang and Sha from 2010. However, as previously discovered in the UK by Dulaimi et al., 2017b, CMA can take between 2 and 24 months to fully cure, depending on the environment, in addition to the fact that standard CMA with limestone filler is vulnerable to rainwater damage in its early stages of life. The most typical applications for CMA in the UK and globally are surface treatment, including surface dressing and slurry surfacing, and reinstatement work on low-trafficked roads and pathways. Lime has also been employed by certain researchers to improve CMA. According to test results from a study by Dash and Panda (2018), adding more lime filler to CMA boosts its Marshall stability, and 2% lime provided satisfactory results. In contrast to granite and granite filler, Wang and Sha (2010) demonstrated that limestone and limestone filler enhanced durability. Lime uses also decreased the depth of ruts.

Fly Ash

Typically, fly ash is used as filler. Fly ash has several different characteristics, making it a very stable filler for use in cold bituminous mixes. Research showed that the resilience modulus and dynamic creep were improved by the oil shale fly ash alteration. A study by Kazal, (2015) expressed, mixes with lime and fly ash demonstrated improved stability to a limited amount of substitution and led to a greater air void content as the percentage of substitution increased. Fly ash is also a waste product. Using it benefits CMA by making it more cheap and environmentally sustainable (Jain & Singh, 2021).

Fibre

Fibre reinforcement increases resistance to cracking and permanent deformation, which prolongs fatigue life and delays further rutting. To do this, various types of fibres are employed to improve the bituminous mixtures' engineering qualities (Abtahi et al., 2010). When compared to employing only asphalt mixtures, fibres with high tensile strength have a better possibility of enhancing the tensile strength and cohesiveness of asphalt mixtures (Xue and Qian, 2016). These fibres' primary functions as reinforcing materials are to boost the mixes' tensile strength and raise their strain resistance to fatigue cracking and permanent deformation (Abtahi et al., 2010).

When used as a reinforcing material, fibres primarily serve to increase the tensile and shear strength of the resulting mixtures and to generate the proper level of strain resistance throughout the mixture's rutting and fatigue processes (Abtahi et al., 2010). Vale et al., (2014) stated, as their mechanical qualities are improved, fibres in bituminous mixes can help lessen the mixtures' tendency to drain down, while also improving ductility (Qian et al., 2014). By bearing tensile strains to stop crack formation and spread, Saeidi and Aghayan in 2016 said that fibre-reinforced bituminous mixes act as a crack barrier. The results of tests by Shanbara et al., (2018) indicate that fibres have increased the CMA mixes' fracture toughness.

Jain & Singh, (2021) in their research has also found out that the time required for mixtures to cure was also shown to be shortened by fibre inclusion. The study further determined that the kind and quantity of fibres significantly changes the qualities of cold mix based on the results of samples containing different fibres.

Drawing from these research findings, it can be concluded that the incorporation of fibers enhances various properties of CMA. This includes its performance under extreme temperatures and its ability to resist cracking and rutting. The utilization of fibers, nanomaterials, and modified asphalt emulsion holds potential in the design of CMA. Given their influence on CMA's characteristics, both laboratory and field performance assessments are warranted (Dash et al., 2022).

Conclusion

This paper undertakes a comprehensive review of the literature on Cold Mix Asphalt as a long-term road resurfacing solution. It investigates the potential of Cold Mix Asphalt to serve as a permanent solution for road resurfacing, considering the merits, drawbacks, and methods for improving its performance. Additionally, it elucidates the advantages of CMA in promoting environmental sustainability, social well-being, and economic aspects by drawing from various sources. It also encourages the usage of CMA which supports the objective of SDG 7 since it is an affordable, reliable, sustainable and modern energy option. On top of that, it hopes to encourage more research to fully utilize the potential of CMA and the maximum capability of it for the betterment of our community and environment.

This paper offers an overview of the advantages and disadvantages associated with CMA, which are presented as follows:

i) Benefits

- Manufacturing is feasible at room temperature
- No heating is necessary for the mixture
- Lower energy requirements
- Reduced labour hours compared to HMA
- Contributes to cost reduction
- Mechanical strength improves over time
- Aids in pollution reduction

ii) Drawbacks

- Curing time for CMA is lengthier
- Initial strength is relatively weak
- Compared to HMA, it exhibits diminished strength

To enhance the role of CMA and establish it as a long-term resurfacing solution, standardizing the mix design for CMA is crucial to ensure the production of a robust and dependable mixture. This standardized design should address the challenges encountered by CMA when compared to HMA. Additionally, incorporating environmentally friendly additives is imperative, as the objective is to achieve a CMA that is both strong and environmentally friendly. In conclusion, CMA should not only be a valuable solution for permanent resurfacing but also a contributor to environmental sustainability. This can be achieved by gathering more interest in finding out the maximum capabilities of CMA.

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