Microsurfacing as a Sustainable Road Solution: Environmental and Economic Perspectives

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Abstract- Microsurfacing has been employed globally as an effective pavement maintenance technique. This review paper examines the advantages, disadvantages, and critical factors for the successful implementation of microsurfacing. It provides a comprehensive history of microsurfacing and discusses its evolution over time. The paper details the materials involved and elaborates on the application process. By synthesizing current research, the paper highlights the efficacy of microsurfacing in maintenance programs. Furthermore, microsurfacing can address environmental and financial concerns. The paper provides recommendations for future research aimed at enhancing the application and performance of microsurfacing, with particular emphasis on its cold-applied method and the incorporation of polymers in the bitumen.

INTRODUCTION

Pavement preservation is a proactive strategy aimed at maintaining and extending the lifespan of road networks. Unlike traditional maintenance, which addresses severe deterioration, pavement preservation involves treatments to prevent significant damage, improving functionality and delaying costly repairs.

The need for pavement preservation is driven by the high costs of major repairs, the demand for high-performance roads, and the goal of maximizing infrastructure investment returns. Properly preserved pavements enhance safety, reduce vehicle operating costs, and lower emissions due to smoother rides. Preservation also minimizes traffic disruptions and enhances user satisfaction. Recent innovations in highway maintenance have embraced a range of technological advancements, including pavement smoothness specifications, open-graded drainage layers, perpendicular transverse joints in concrete pavements, ultra-thin whitetopping, stone mastic asphalt, micro-surfacing, and expanded/foamed asphalt[10].

For rigid pavements, preventive maintenance techniques include joint sealing to prevent water infiltration, diamond grinding improves ride quality by removing surface irregularities, and partial-depth repairs fix localized distress without full slab removal and slab stabilization using methods like slab jacking. For flexible pavements, techniques involve surface treatments such as chip sealing to restore surface integrity and crack sealing to prevent further damage.

Microsurfacing is considered one of the preventive maintenance techniques rather than a corrective one, owing to its effectiveness in sealing and restoring pavement surfaces[1]. While some sources categorize microsurfacing as primarily preventive, routine, or corrective maintenance, its flexibility as a thin coating—typically applied at a thickness of two to three times the size of the largest aggregates—supports its use in various conservation contexts[3]. Microsurfacing, a thin, cold-laid mixture, restores surface texture, skid resistance curing quickly to minimize traffic disruption. Widely used on highways, urban roads, and airport runways, microsurfacing extends pavement life and enhances surface quality. Microsurfacing is a cost-effective technique using a polymer-modified asphalt emulsion mixed with aggregate[4]. It restores surface characteristics and improves skid resistance, curing quickly to minimize traffic disruption. Widely used on highways, urban roads, and airport runways, microsurfacing extends pavement life and enhances surface quality.

MICROSURFACING

Microsurfacing was developed in Germany during the late 1960s and early 1970s and was initially designed to apply a traditional slurry in sufficiently thick layers to address deep wheel ruts while ensuring that road striping lines on autobahns remained intact. The technique was introduced to the United States in 1980 when Dr. Frederick Raschig showcased his new slurry system, Ralumac, at the International Slurry Surfacing Association (ISSA) convention[7]

Many highway issues arise from poor bonding between base layers and coatings, or between old and new pavements. Slippage between layers is a frequent problem in these scenarios[14]. Additionally, displacements, cracks, and early deterioration of the upper layer can occur, significantly reducing the pavement's lifespan[15]. Microsurfacing helps maintain pavement strength and is suitable for both preventive and periodic renewal treatments on roads with low to medium traffic. It can be applied to pavements in both urban and rural areas, including primary and inter-state routes, residential streets, highways, and toll roads. It can also be used over single coat surface dressing (Cap Seal), open-graded premix carpet without a seal coat, and Dense Bituminous Macadam/Bituminous Macadam.

Microsurfacing involves a blend of modified bitumen emulsion (such as polymer or rubber latex), mineral aggregate, water, and optional additives, which are proportioned, mixed, and evenly spread over a properly prepared surface[5]. The finished microsurfacing layer should form a uniform mat that firmly adheres to the prepared surface and provides a friction-resistant texture throughout its service life. The mix is designed to set quickly, allowing traffic to resume within about two hours, depending on weather conditions[8]. This method serves as a surface sealing treatment to improve skid resistance, surface durability, and to seal fine and medium cracks. It is applied to existing pavement surfaces that are structurally sound but show signs of aging, aggregate loss, cracking, and significant polishing. While typically applied in a single layer, surfaces that are highly polished or cracked may require multiple layers. Microsurfacing extends the service life of pavements by 4.9 to 8.8 years[9]. Most studies focus on adhesion between different grades of asphalt concrete layers[16]. In concrete pavements, micro-surfacing helps improve and maintain surface friction and smoothness[17]. These studies suggest that factors such as temperature, binder application rate, type of binder, pavement surface, and aggregate grade significantly influence the bond strength between pavement layers[18].

Micro-surfacing proves effective in addressing surface distresses in asphalt concrete, such as ravelling, segregation, loss of friction, rutting, and minor cracking. It is capable of filling ruts up to 25 mm deep and serves as a preventive maintenance treatment to seal pavement surfaces against water intrusion. The shear strength of pavements arises from the interlocking of aggregates and the bonding between layers within the pavement structure[11]. Shear strength can be assessed through shear, torsion, and tensile tests, with shear tests being the most commonly employed method[12]. The shear strength between two layers in pavement is impacted by factors such as temperature, coating type, asphalt application rate, and the grade of aggregates used[13].

Although micro-surfacing is widely used in Brazil and globally for maintaining pavements with preserved structural capacity, there is still a lack of research on adhesion resistance behavior between micro-surfacing and flexible/rigid pavements. Micro-surfacing, extensively utilized in Brazil for preventive maintenance, enhances skid resistance, improves ride comfort, protects the pavement structure from water damage, and extends the pavement's lifespan[4]. Furthermore, micro-surfacing can address depressions and rapidly restore the road to traffic use[20].

LITERATURE REVIEW

1. Yaofei Luo, Ke Zhang, Xiangbing Xie, Xiaoguang Yao. (2019). “Performance evaluation and material optimization of Micro-surfacing based on cracking and rutting resistance”.

The research aimed to improve the performance of Micro-surfacing by using different additives such as Waterborne Epoxy Modified Emulsified Asphalt (WEMEA), Styrene Butadiene Styrene (SBS) modified emulsified asphalt, and fiber stabilizer. The study conducted various tests, including low temperature bending and Hamburg Wheel-Track Testing, to analyze the impact of these additives on Micro-surfacing properties. The results showed that the addition of fiber had a significant positive effect on the performance of Micro-surfacing, particularly in improving low temperature performance. The type and dosage of fiber used also influenced the properties of Micro-surfacing, with the compound use of polypropylene fiber and basalt fiber showing technical advantages and cost reduction. Based on the performance and economic considerations, the optimal fiber dosage was recommended to be in the range of 0.10% to 0.20% by the weight of the asphalt mixture. The findings of this research provide valuable insights for the application and promotion of fiber Micro-surfacing, highlighting the importance of fiber selection and dosage optimization.

2. Kamaraj, Chidambaram & Lakshmi, S. & Rose, C. & Mani, Uthirappan & Paul, E. & Mandal, Asit & Gangopadhyay, S. (2016). “Experimental study on micro surfacing using chrome shaving impregnated with modified bitumen emulsion”.

The study explored the innovative use of chrome shavings (CS) as a filler in micro surfacing for pavement preservation, addressing significant waste disposal issues from the leather industry. With the industry generating approximately 600,000 tons of solid waste annually, a substantial portion comes from shavings and trimmings. Trivalent chromium sulfate (Cr(III)), used in the tanning process, leaves a notable amount of unreacted chromium, resulting in CS composed of collagen and Cr(III). This research aimed to repurpose CS in micro surfacing mixtures, which include dense-graded aggregate, polymer-modified bitumen emulsion, mineral filler, and water[6]. Experimental applications on heavily trafficked and light traffic roads in Chennai, India, demonstrated the feasibility and benefits of using CS. The findings indicated that CS not only aids in waste management but also enhances pavement preservation, contributing to sustainable road construction practices.

3. Kumar, Rajiv & Ryntathiang, Teiborlang. (2016). “New Laboratory Mix Methodology of Microsurfacing and Mix Design”.

This article focuses on evaluating proven combination methodologies for mixing emulsion with coarse and fine aggregates in microsurfacing. A different mixing technique was investigated to address the issue of balling during the mixing process. The mix methodology was developed and adopted for analyzing type II and type III microsurfacing gradations. Various tests were conducted, including break time, fixed times, and consistency tests with different water content, following the mixing methodology. The consistency values were within the range of 2-4 cm, meeting the criteria set by the ISSA Technical Bulletin for type II and type III microsurfacing. The article also discusses the determination of the optimum residual bitumen content using a modified marshalling test. The optimal residual bitumen content was found to be 10% at 4% air voids for type III gradation and 7.7% for type II gradation. The flow, air voids, VFB (Voids Filled with Bitumen), and VMA (Voids Filled with Mineral Aggregate) met the Marshall criteria requirements at these optimal bitumen contents.

4. Pittenger, Dominique & Gransberg, Douglas. (2019). “Life cycle cost analysis of Portland cement slurry seal and microsurfacing to correct rutting”.

Portland cement slurry seal (PCSS) and microsurfacing are both used for pavement preservation to fill ruts, extending service life and reducing lifecycle costs. Microsurfacing has a proven history of being effective and cost-efficient for both asphalt and concrete pavements. In contrast, PCSS is a newer alternative that is less recognized and underutilized for rut filling. This study compares the life cycle costs of PCSS and microsurfacing, using friction data from field trials over 36 months. The results show that both treatments perform similarly in terms of surface friction deterioration, making them economically viable options for rut filling. Economic analysis indicates that when unit costs are low, service life is crucial: PCSS is preferred with a 12-year service life, while microsurfacing is favored for a 6-year service life. At high unit costs, PCSS generally has higher Equivalent Uniform Annual Cost (EUAC) values compared to microsurfacing. For PCSS to be comparable, it must achieve a 12-year service life.

5. Ilias, Mohammad & Adams, Javon & Castorena, Cassie & Kim, Y.. (2017). “Performance-Related Specifications for Asphalt Emulsions Used in Microsurfacing Treatments”.

Their study focused on addressing critical distresses rutting and thermal cracking in microsurfacing binders. Assessing fresh emulsion properties, they identified storage stability and mixability as crucial constructability concerns. Key tests for rutting and thermal cracking included the multiple stress creep and recovery test and dynamic shear rheometer frequency sweep test, respectively. The proposed EPG specifications for fresh emulsion properties were determined through statistical analysis of binder test results, providing valuable insights for enhancing the constructability and performance of microsurfacing treatments.

6. Al-Hosainat, Ahmad & Nazzal, Munir & Talha, Abu & Kim, Sang Soo & Abbas, Ala & Mohammad, Louay. (2022). “A comprehensive

laboratory evaluation of the factors affecting the Micro-Surfacing interlayer bond strength."

This study evaluated the effects of tack coat and micro-surfacing mix properties on the bond strength between micro-surfacing layers and asphalt pavement surfaces. Key factors included tack coat material, application rate, residual asphalt binder content, the number of micro-surfacing layers, and pavement surface texture. Tests showed that samples without tack coat had significantly lower bond strength. An application of at least 0.05 gallons per square yard (0.0068 gsy residual rate) improved bond strength, while reducing residual asphalt binder by 0.75% decreased it. Double micro-surfacing layers generally had lower bond strength than single layers. The tack coat application of at least 0.03 gsy between layers improved bond strength, though not always significantly.

7. Jianbing, Lv & Huang, Juan & Wu, Hao & Zhang, Yang & Qiu, Jingyu & Sun, Xiaolong & Yin, Yingmei & Sun, Xiaoli. (2021). "Experience Study on Long-Life Microsurfacing with High Water Resistance Performance".

In Guangdong Province, traditional microsurfacing faces challenges like poor water resistance and short service life due to high temperatures and heavy rainfall. To address this, a new approach called high-performance microsurfacing has been developed. By blending water-based epoxy resin and waterborne epoxy curing agent, this method creates a durable, chemically bonded network structure. Lab tests show high-performance microsurfacing improves wear and water damage resistance by over 50% compared to traditional methods. Long-term road performance also demonstrates better antisliding and water resistance. This innovation offers significant benefits: it extends service life by about 60% and surpasses conventional microsurfacing in antisliding and spalling resistance. Proper dosage of water-based epoxy additives is crucial, with a recommended content of 2%. Despite a minor increase in engineering cost (3–6 yuan per square meter), high-performance microsurfacing presents promising prospects for enhancing pavement durability in challenging climates.

MATERIAL

Microsurfacing is a mixture of aggregate, filler, water, additive, and emulsion proportioned by weight of aggregate. Aggregate, modified bitumen emulsion, water, and additive (if used) shall be proportioned by weight of aggregate utilizing the mix design[5]. If more than one type of aggregate is used, the correct amount of each type of aggregate is required to produce the desired grading. This ensures a uniform and homogeneous blend.

Microsurfacing, a notable bituminous mixture, includes crushed, densely graded aggregate with a maximum size of about 10 mm, which ensures internal stability and high skid resistance. The mixture also contains emulsified asphalt, allowing for mixing and placement at ambient temperatures, with around 7% asphalt cement by weight. A polymer additive, typically latex, is included to enhance stability and flexibility, representing approximately 3% of the asphalt weight. Additionally, mineral filler, often Portland cement, is used to control the set times of the micro-surfacing material, constituting about 1% of the total dry mix weight.

Aggregates

The aggregate should be a high-quality crushed stone, such as granite, slag, limestone, chat, or a combination of these materials as shown in Table 1. These sources primarily provided coarse aggregates, fine aggregates, and similar types of mineral fillers. The acceptable specification values are considered according to ISSA A143.

Sieve size	**Microsurfacing**	
	Type II	**Type III**
mm	(4-6mm)	(6-8mm)
9.5	-	100
6.3	100	90-100
4.75	90-100	70-90
2.36	65-90	45-70
1.18	45-70	28-50
0.6	30-50	19-34
0.3	18-30	12-25
0.15	10-21	7-18
0.075	5-15	5-15

Table 1: Aggregate gradation

The compatibility between aggregates and asphalt emulsion is crucial in the microsurfacing mixture design process and affects the operation time[1]. Aggregate surface area and binder emulsion residue significantly impact micro-surfacing performance. Larger surface areas reduced adhered sand in loaded wheel tests and increased aggregate loss. Modified grading (MG) aggregates showed superior rut resistance compared to UG and LG, making it ideal for high-traffic areas[28]. Research has shown that aggregate gradation significantly affects the performance of cold mixes. Specifically, thinner lift thicknesses with coarser gradations tend to be more susceptible to moisture damage compared to thicker lifts with finer gradations[29].

Emulsion

The characteristics of the emulsion are crucial for determining the workability and durability of microsurfacing, which in turn affects its final performance. These properties are primarily influenced by the design and selection of components used in its production, including the type and dosage of emulsifier, acid content, binder grade and content, and the type and dosage of polymer modifier[32].

The materials utilized includes two varieties of aggregates and two types of asphalt emulsions: cationic quick setting (CQS-1h) and cationic slow setting (CSS-1h)[1]. The efficiency of emulsions in forming cohesive bonds is influenced by the electric charge imparted by surfactants, which affects how well the emulsion combines with aggregates. Studies indicate that granite aggregates and quick-setting emulsions offer superior adhesiveness against abrasion[30], a key challenge in micro surfacing.

However, there are limitations in these studies, such as the lack of a standardized benchmark for comparing different binder types and the failure to link aggregate types to specific gradations as outlined by ISSA[31]. Further research is needed to explore the detailed interactions between aggregates, emulsions, and polymers, to provide a more comprehensive understanding impact of material types on microsurfacing performance

Water

In micro-surfacing, water is present in three forms: within the mineral aggregate, in the emulsion, and as additional water. The additional water typically constitutes about 6%–11% of the dried mineral aggregate's weight[33]. It is crucial to strictly control the amount of additional water, as this control is essential for maintaining consistency and achieving the desired paving effect in micro-surfacing.

Filler

Another crucial factor in microsurfacing mix design is the type and amount of filler used. This is important because fillers, with their large surface area, play a significant role in the breaking and curing process. Typically, the mixtures contain 0–3% mineral filler, most commonly Portland cement[32] and maintain a fixed cement content of 2% and fiber content of 0.5%. Starting with a predicted optimum emulsified asphalt content of 7%, adjust the emulsified asphalt content in 0.5% increments. To keep the total fluid content constant, modify the corresponding mixing water as the emulsified asphalt content is changed[34]. The optimal asphalt-aggregate ratio range for the fiber micro-surfacing mixture was determined through various tests, including the wet track abrasion test, the load wheel test, the stability and resistance to compaction test, and the cohesion torque test.

METHOD- MIXING & LAYING

For optimal results of microsurfacing, it is essential that the existing flexible or rigid pavement is structurally sound and properly prepared before applying microsurfacing[2]. Microsurfacing asphalt mixtures are commonly used for pavement maintenance, serving as a protective surface layer that addresses issues such as skid resistance, raveling, or oxidation on structurally sound pavements[35]. They enhance the overall characteristics of the road surface. The cold mix formula created in the lab may differ from its application on the road due to varying conditions, particularly temperature[36]. Therefore, it is an approximation that requires adjustment in the machine. To ensure proper mixing in microsurfacing, materials must enter the mixer in the correct order and time. First, aggregate falls into the main hopper, controlled by a gate, then moves via a conveyor belt to the mixer. Adjusting the gate and belt speed regulates aggregate volume and production rate. Next, filler (usually cement) is added from a small hopper using belts and augers. Asphalt emulsion and water, stored in front tanks, are pumped into the mixer last. Precise synchronization ensures thorough mixing.

When laying microsurfacing, proper connection of the spreader box to the machine is crucial for synchronized movement. Regular checks of hydraulic hoses maintain auger functionality. Continuous auger mixing prevents material separation during distribution. Intact rubber strips around the spreader box prevent material leakage and ensure uniform thickness. Cleaning rubber strips after each use is essential. Automatic spreader box adjustments help control microsurfacing thickness, with regular maintenance ensuring process efficiency.

FINANCIAL IMPACT

An analysis of pavement preservation treatments found chip plus fog seal and micro-surfacing to be the most economical and environmentally friendly, using the least embodied energy and emitting the least carbon. Full-depth reconstruction and mill and fill were the least economical, with the highest energy consumption and emissions. Treatment selection depends on environmental conditions, material availability, and traffic volumes[37]. Proximity of quarry sites, treatment plants, and construction sites is crucial for reducing energy use and emissions. An expertly defined LCA system is vital for green procurement, optimizing material use, and minimizing costs and emissions in road construction.

Including materials, labor, and other construction expenses, microsurfacing is a cost-effective option for road maintenance. User delay costs, which arise from slowed traffic during construction, are typically factored in using models that estimate additional fuel consumption and traffic delays. These estimates are generally conservative, as much of the work is often performed at night to minimize delays[6]. Chip seals are the least expensive treatment option, with minimal cost variability, making them an attractive choice for budget-conscious projects. Microsurfacing, while slightly more expensive, still offers a reasonable cost with some variability. Thin overlays are the most expensive and variable option, making them significantly costlier than both microsurfacing and chip seals[38]. Studies have shown that microsurfacing can result in substantial cost savings, offering a 31% reduction in costs compared to conventional hot-mix asphalt. This highlights microsurfacing as a viable and economical choice for road maintenance projects.

The likelihood that a pavement maintenance (PM) treatment is more cost-effective (lower LCC) than another is crucial for sensitivity analyses and decision-making under uncertainty. Using 1,000,000 Monte Carlo simulations, the analysis showed that chip seals have a 70% probability of being more cost-effective than microsurfacing and an 85% likelihood compared to thin overlays, indicating their overall effectiveness as preventative maintenance options. Microsurfacing has a 75% probability of being more cost-effective than thin overlays. These results offer a preliminary cost comparison of PM treatments, guiding practitioners in decision-making when information is limited.

ENVIRONMENTAL IMPACT

Moreover, microsurfacing is produced at lower temperatures (up to 40 °C), which contributes to energy savings, reduces greenhouse gas emissions, and minimizes occupational hazards compared to hot mix asphalt[39]. Mill and fill using hot mix asphalt demands higher production and application temperatures and uses more asphalt and aggregate compared to microsurfacing. Consequently, microsurfacing consumes approximately 40% less primary energy than mill and fill over its life cycle[40].

Even when incorporating Reclaimed Asphalt Pavement (RAP) in the asphalt mix overlay, studies indicate that microsurfacing uses over 50% fewer resources by mass. Air emissions, which are the most significant category in the study, include greenhouse gases, photochemical ozone creation potential (summer smog), acidification potential, and ozone depletion potential[41]. Microsurfacing can reduce road noise exposure by an average of 30 meters during the day and 50 meters at night[43].

The production process of hot mix asphalt involves drying the aggregates (both coarse and fine) at high temperatures before mixing them with bitumen and filler. This procedure is a significant source of carbon emissions and energy consumption[37]. Notably, type III aggregate gradation demonstrates a relatively lower impact in terms of both emissions and energy usage compared to other gradations. Full-depth reconstruction, thin overlay combined with mill and fill, and thin overlay alone are the most energy-intensive treatments due to the extensive production processes and transportation of materials required. These treatments demand substantial heating of aggregates and large quantities of materials per unit area, resulting in high embodied energy.

In contrast, treatments like chip and fog seal, micro-surfacing, and their combination are far less energy-intensive. The difference in embodied energy consumption between the most and least intensive treatments is substantial, highlighting the potential for significant energy savings by choosing less intensive options. This energy saving could be utilized to preserve additional kilometers of road pavement, emphasizing the importance of selecting sustainable practices in road construction and maintenance.

CONCLUSION

Microsurfacing process is effective in extending the pavement life and improving surface texture. Compared to traditional hot-mix asphalt methods, microsurfacing generates lower carbon emissions and requires less energy. Microsurfacing generates approximately 53% fewer carbon emissions and 47% less energy consumption compared to traditional hot-mix asphalt methods. It significantly reduces the environmental footprint by minimizing aggregate heating and material transportation needs. Microsurfacing is more economical than other pavement treatments like thin overlays and full-depth reconstruction. Microsurfacing is around 31% less expensive than conventional hot-mix asphalt. It is also about 69% cheaper than thin overlays, making it a highly economical choice for pavement maintenance. Its lower material and labor costs, along with reduced user delay expenses, make it a financially viable option.

Microsurfacing offers a balance between cost and environmental sustainability. It provides substantial cost savings while contributing to environmental preservation by reducing emissions and energy consumption. The lower cost and environmental benefits of microsurfacing make it an attractive choice for road maintenance projects. It is particularly suitable for regions seeking to optimize road maintenance budgets while adhering to environmental regulations.

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