


# Chapter 9

## Sustainable Pavement Solutions: A Project-Based Economic Assessment of RAP Usage

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### ABSTRACT

*This study examines the technical and economic effects of incorporating Reclaimed Asphalt Pavement (RAP) and basalt fiber into asphalt mixtures within the framework of sustainability and circular economy principles. Twelve mixtures with varying RAP (0–45%) and fiber (0–3%) contents were tested using the Tensile Strength Ratio (TSR) and Hamburg Wheel Tracking methods. Results showed that RAP significantly improved rutting resistance and reduced costs, achieving up to 34% savings at 45% RAP. Although basalt fiber slightly increased initial costs due to higher bitumen demand, it enhanced durability and reduced long-term maintenance needs. Overall, RAP supports circular economy goals by lowering material and energy use, while basalt fiber strengthens mechanical performance, offering a balanced and sustainable pavement solution.*

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## INTRODUCTION

Sustainability has become a central concern in transportation infrastructure engineering, driven by both environmental pressures and economic constraints. Rising construction costs, increasing scarcity of natural resources, and the impacts of global climate change have collectively pushed pavement engineering toward greater use of innovative and recycled materials. In this setting, reclaimed asphalt pavement (RAP) has gained attention as a practical material that is consistent with circular economy principles and capable of delivering measurable environmental and economic benefits.

RAP is produced through milling or full-depth removal of existing asphalt layers and can be reused in the manufacture of new hot or warm mix asphalt. Its use enables road agencies to limit the demand for energy-intensive virgin materials, particularly bitumen and aggregates (Al-Qadi et al., 2007; Giani et al., 2015). When applied at suitable replacement levels, RAP contributes to reduced resource consumption while also lowering material costs. Nevertheless, its application should be evaluated not only in terms of mechanical performance but also with respect to economic viability, as cost efficiency remains a key factor in sustainable pavement decision-making. Conducting a comprehensive cost analysis can encourage the integration of RAP into engineering projects.

A considerable body of research demonstrates that even high RAP contents can be used effectively without compromising mechanical performance. For instance, Mogawer et al. (2012) found that asphalt mixtures containing up to 50% RAP can meet fatigue cracking, rutting, and moisture susceptibility criteria when properly designed. Wu et al. (2021) showed that the blending and diffusion between aged and virgin binders within RAP can be enhanced with rejuvenators or softer binders, thereby improving mixture homogeneity and durability.

Apart from its technical performance, the environmental benefits of RAP have been widely documented in the literature. Zaumanis and Mallick (2014) reported that RAP significantly reduces greenhouse gas emissions and energy consumption during asphalt production. Aurangzeb et al. (2014), using hybrid life cycle assessment (LCA) techniques, demonstrated that high RAP content mixtures substantially decrease fuel use, CO<sub>2</sub> emissions, and raw material input.

Nevertheless, the widespread implementation of RAP is often influenced by non-technical factors such as policy incentives, regulatory frameworks, contractor expertise, and market availability of RAP material. In many developing countries, the lack of clearly defined limits on RAP usage, together with unclear quality control requirements, introduces uncertainty into its practical application. Some agencies restrict high RAP usage in surface courses due to perceived performance risks. Consequently, there is an increasing need for comprehensive economic as-

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