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Performance of pavements incorporating waste glass: The current state of the art

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ABSTRACT

This paper discusses the engineering properties of waste glass (WG), including its structural and environmental performance, as an alternative material for the construction of various types of paving systems, including asphalt, concrete, and block pavements. As a first step, an overview of the asphalt, cement, and glass manufacturing industries is provided. Then, a large volume of data is analyzed from various sources in the literature. Particular emphasis is given to laboratory studies of the structural performance and durability of WG. Additionally, the effect of WG on the field performance of the pavements is discussed. The sustainability of the pavements is also evaluated in terms of energy consumption, greenhouse gas emissions, safety, and the heat island phenomenon. In conclusion, the use of WG can improve various phases of pavement life and structure by enhancing the structural performance, durability, environmental friendliness, and aesthetic features of pavements.

Contents

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1. Introduction

The volatile carbon-based energy carrier market, growing competition, and global commitments to the reduction of greenhouse gas (GHG) emissions have brought about the recognition of infrastructure assets and construction technology as untapped opportunities. Energy efficiency, which covers sound plant-wide energy management practices associated with environmental management and protection strategies, offers additional advantages, as do sustainable design and construction based on reclaim, recycle, reuse, and reduce (4R) policies. Therefore, infrastructure assets and industrial products should fall under at least one of the 4R policies, as a minimum requirement, or preferably all of them under ideal conditions, leading to significant improvements in efficiency and productivity. For example, a 90% reduction in energy and material consumption produces a tenfold increase in resource productivity [1].

One of the largest demands by human society is the transportation system, supported by the most important transportation infrastructure assets, which can be considered to be the backbone of socio-economic development. However, more energy-efficient and sustainable transportation infrastructure assets are required as integral parts of a sustainable society. To meet this requirement, many advanced technologies have been developed. For example, the entire fuselage and most of the wings of the Boeing 787 Dreamliner are built from carbon fiber-reinforced plastics, which is four times more than the Boeing 777. This makes the Boeing 787 lighter, resulting in a 20% savings in jet fuel and air emissions, which is fully in harmony with green design [2]. As another example, the amount of energy consumption per seat on the new-generation Japanese high-speed bullet train, *Shinkansen,* is 12.5% that of a Boeing 777, indicating its great environmental superiority [3]. The construction, maintenance, and rehabilitation of infrastructure assets depend on non-renewable natural resources.

There are also constant efforts to fulfill the requirements of 4R policies for infrastructure assets. Among the many transportation infrastructure assets and accessories, pavements are among the most valuable, because many materials supplied from non-renewable natural resources are used for their construction. One approach to complying with 4R policies is the use of waste materials in pavement. Thus, there are an increasing number of ecological, economic, and engineering incentives for using waste materials in pavement construction, including the following [4–6]:

(i) A shortage of natural aggregate material resources,
(ii) High cost of landfill,
(iii) Commitment to the environment,
(iv) Resource conservation,
(v) Availability,
(vi) Political pressure,
(vii) Environmental safety,
(viii) Efficient use of materials, and.
(ix) Increased productivity.

Under such circumstances, the use of waste material under 4R policies provides economic value because using waste materials as raw materials increases the recycling rate. The role of 4R policies is pronounced when the amount of waste materials generated is considered. In 2000, global mining activity produced 6 Gt of mine wastes, compared with only 900 Mt of raw materials [7], which means that 1.5 t of waste material was generated in the production of 1 t of raw material. This amount of waste material is a concern when considering that approximately 60 Gt of raw materials was used annually across the globe in the 20th century. As a result of the large amount of waste material that has been produced, it is essential to utilize well-run sustainable construction programs to solve the growing waste disposal crisis.

Furthermore, sustainability and environmental stewardship are now in a conceptual stage as part of pavement analysis, design, and construction, because there are various analytical methods