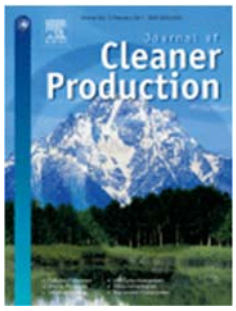
Journal of Cleaner Production
Volume 283, 10 February 2021, 124581



Review

Waste materials in highway applications: An overview on generation and utilization implications on sustainability

Author links open overlay panelGideon O. Bamigboye [a], Daniel E. Bassey [a], David O. Olukanni [a], Ben U. Ngene [a], Dunmininu Adegoke [a], Abimbola O. Odetoyan [a], Mutiu A. Kareem [b], David O. Enabulele [a], Austin T. Nworgu [a]

[a] Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria

[b] Department of Civil Engineering, Osun State University, Osogbo, Nigeria

Received 14 May 2020, Revised 29 August 2020, Accepted 5 October 2020, Available online 8 October 2020, Version of Record 4 January 2021.

What do these dates mean?

Handling Editor: Prof. Jiri Jaromir Klemeš

https://doi.org/10.1016/j.jclepro.2020.124581Get rights and content

Abstract

The rate at which the construction industry explores and consumes non-renewable natural aggregates and other industrial products such as bitumen, lime, and cement during construction and rehabilitation of road pavements has over time proven to be environmentally degrading and non-sustainable. This, alongside the issues of high solid waste generation and inadequate disposal, has led to series of studies by various researchers to find methods to integrate these solid wastes as alternative materials in road construction and maintenance. This paper provides a simple yet detailed review of recent relevant studies conducted to understand the alarming rate of generation and the effects of reusing these waste materials in both flexible and rigid pavements. The review further outlines the advantages and disadvantages of the selected waste materials and compare the results with that of conventional materials in accordance with relevant standards while highlighting the performance, and life cycle environmental and economic sustainability implications. The study shows that the adoption of these materials offers efficiency in waste disposal while reducing the demand for natural aggregates and consequently, significantly reducing life cycle impacts and costs. The challenges limiting the effective practical implementation of these waste recycling techniques in the construction industry were discussed and possible solutions were suggested to encourage and ensure its utilization in road construction.

Introduction

While the need for construction and maintenance of roads and other highway facilities remains a key factor in the socio-economic development of a society, it has over time began to pose negative externalities on the environment. Road pavement construction often involves the exploration of high volumes of materials (mostly aggregates) and mass haulage which result in increased emissions of greenhouse gases (Majer and Budziński, 2018). According to Garside (2019), over 257 million metric tons of sand and gravel was produced in the year 2017 by the leading countries in sand and gravel exploration. The USA accounts for about 102 million tons out of that. Yet in the year 2018, another 277 million metric tons of aggregate was produced for industrial purposes. The current exploration rate does not seem to be in line with the United Nations Development Program's (UNDP) sustainable development goals that drive sustainable construction alongside environmental protection by minimizing the utilization of natural resources (Huang et al., 2007). The continuous rise in global economy and standard of living will surely result in an increased rate of raw material consumption worldwide. A report by the Organisation for Economic Co-operation and Development (OECD) projects that by 2060, the use of natural raw materials (especially metals and non-metallic minerals) will rise to about 167 gigatons from 90 gigatons today, while world population is also expected to rise to about 10 billion people (Weber and Kroll, 2019).

To tackle this, various researchers have in the last two decades studied means of incorporating sustainable materials in road construction to support conservation. Some of these methods include the reuse of selected waste materials such as construction and demolition wastes (Stehlik et al., 2015; Zhang et al., 2019), glass waste (Kadhim et al., 2019), Waste tire rubber (Bonicelli et al., 2017), fly ash and granulated blast furnace slag (GBFS) (Bakare et al., 2019), colliery spoils (Suescum-Morales et al., 2019), polyethylene terephthalate (PET) (Sojobi et al., 2016), mine tailings, shingles

(Haas et al., 2019), aluminium dross (López-Alonso et al., 2019), and bio oils (Kousis et al., 2020) to list a few, in the construction and rehabilitation of roadways. These materials have been evaluated separately or alongside other waste materials as a full or partial replacement for certain traditional construction materials.

The need for material diversification can also be ascribed to the rising need for durability, increased performance, and reduced maintenance and construction costs in road pavements, especially in developing countries (Sojobi et al., 2016). The rapid rise in population brings about an increase in vehicular traffic and axle loads resulting in road section failures (Ede, 2014). These failures mostly occur either at the bottom of the surfacing layer (fatigue and cracking due to tensile stresses between layers) or at the subgrade layer (rutting due to compressive forces from wheel load) (Indian Road Congress (IRC), 2012). Fig. 1 illustrates the basic layers in road pavements and indicates failure points.

This paper reviews recent relevant literature to compare various sustainable materials and methods that have been adopted in the modification of conventional road pavement materials. The generation rate and application of the selected waste materials, and their effects on the physical and mechanical performance of road pavement was reviewed. The environmental and economic implications resulting from the utilization of these waste material on sustainability were also discussed.

Section snippets

Generation and management of selected waste materials

The rising complexity and volume of solid waste generated continue to pose grave threats to the ecosystem and public health. According to the UNEP (2019) survey, about 11.2 billion tons of solid waste is collected worldwide annually, the decay of the organic fraction accounts for about 5 percent of emissions of greenhouse gas globally. Poor management of these wastes (from collection to disposal) causes reductions in air, water, and soil quality. Some of the highly generated wastes that have

Polyethylene terephthalate (PET) utilization

Sojobi et al. (2016) studied the use of PET coated aggregates (PCA) and PET modified bitumen (PMB) in the production of bituminous asphaltic concrete and compared both results to that of conventional bituminous asphalt. Laboratory tests showed that penetration values of PMB decreased as PET increased indicating increases in stiffness and softening point while ductility values, on the other hand, increased with increasing PET content indicating a more stable asphalt. For both PCA and PMB,

Sustainability implications of waste utilization

The utilization of waste materials in the road construction industry poses certain implications on the state of sustainability especially in the environmental, economic, and performance aspects. These implications are discussed in this section.

Discussions

Based on the reviewed studies utilizing different waste materials in highway works, this section presents three facets of the literature to guide utilization practices: the prospects driving the incorporation of these wastes in pavement applications, the challenges faced during practice, and recommendations to avoid or reduce certain challenges.

Conclusions

Several researchers have studied methods in which various solid waste materials can be utilized in the road construction industry. Adequate practical utilization of these materials will lead to significant improvements in the recycling rate of these municipal and industrial solid waste. This concept effectively reduces land requirements for landfills, preserves natural aggregates against depletion, and reduces construction and maintenance costs while improving certain performance criteria.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors wish to thank the chancellor and the management of Covenant University for the platform made available for this research work.

References (217)

- N.T. Abdel-Ghani *et al.*

  Utilization of by-pass cement kiln dust and air-cooled blast-furnace steel slag in the production of some “green” cement products
  HBRC J.
  (2018)
- J.S. Adiansyah *et al.*

Life cycle cost estimation and environmental valuation of coal mine tailings management
J. Sus. Min.
(2017)
- A.A. Al-Homidy *et al.*

Improvement of geotechnical properties of sabkha soil utilizing cement kiln dust
J. Rock Mech. Geotech. Eng.
(2017)
- A.M. Al-Sabaeei *et al.*

March 10). A systematic review of bio-asphalt for flexible pavement applications: coherent taxonomy, motivations, challenges and future directions
J. Clean. Prod.
(2020)
- E.K. Anastasiou *et al.*

Comparative life cycle assessment of concrete road pavements using industrial by-products as alternative materials
Resour. Conserv. Recycl.
(2015)
- J. Anthonissen *et al.*

Review and environmental impact assessment of green technologies for base courses in bituminous pavements
Environ. Impact Assess. Rev.
(2016, September 1)
- J.P.C. Araújo *et al.*

The importance of the use phase on the LCA of environmentally friendly solutions for asphalt road pavements
Transport. Res. Transport Environ.
(2014)
- A. Arulrajah *et al.*

Cement kiln dust and fly ash blends as an alternative binder for the stabilization of demolition aggregates
Construct. Build. Mater.
(2017)
- A. Arulrajah *et al.*

Tire derived aggregates as a supplementary material with recycled demolition concrete for pavement applications

J. Clean. Prod.
(2019)
- A. Arulrajah *et al.*

Tyre derived aggregates and waste rock blends: resilient moduli characteristics
Construct. Build. Mater.
(2019)
View more references

Cited by (79)

- Characterization of contaminant leaching from asphalt pavements: A critical review of measurement methods, reclaimed asphalt pavement, porous asphalt, and waste-modified asphalt mixtures
2022, Water Research

Citation Excerpt :

After the industrial revolution, the exploitation of natural resources has increased more significantly than ever before, resulting in some environmental problems. Nowadays, industries have begun to change their policies in exploiting natural resources and manipulating the environment to take steps toward sustainable development (Bamigboye et al. 2021). Among all existing industries, the construction industry is recognized as one of the largest consumers of natural resources (Motz and Geiseler 2001, Zhao et al. 2020).
Show abstract

- Waste management in the mining industry of metals ores, coal, oil and natural gas - A review
2022, Journal of Environmental Management

Citation Excerpt :

Many countries decide to explore small deposits of raw materials for which the demand is growing every year. As a consequence, the amount of waste produced also increases (Bamigboye et al., 2021; Nikolić et al., 2019). It is practically impossible to prevent the generation of post-mining waste.
Show abstract

- Molded fiber and pulp products as green and sustainable alternatives to plastics: A mini review
2022, Journal of Bioresources and Bioproducts

Citation Excerpt :

The construction industry has been a promising market for such potential applications as it uses great volumes of materials with a wide variety of characteristics in those materials (functional,

mechanical, and others). Some emerging applications of waste products in construction include concrete plant, brickworks, insulated panels and others (Andrés et al., 2015; Bamigboye, 2021), which is shown in Fig. 3. The MFPs are used with the intent to be discarded after single use post-consumption usage.
Show abstract

- “Functional upcycling” of polymer waste towards the design of new materials
2023, Chemical Society Reviews

- A Comprehensive Review of Biochar Utilization for Low-Carbon Flexible Asphalt Pavements
2023, Sustainability (Switzerland)

- Utilisation of waste-based geopolymer in asphalt pavement modification and construction; a review
2021, Sustainability (Switzerland)

View all citing articles on Scopus
View full text

Article Metrics

Citations

- Citation Indexes:77

Captures

- Readers:322

View details