Construction and Building Materials 467 (2025) 140376

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Modeling an artificial neural network to estimate cement consumption in clayey waste-cement mixtures based on curing temperature, mechanical strength, and resilient modulus

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ARTICLE INFO

Keywords:
Artificial network
Artificial Intelligence
Soil cement
Clay waste
Resilient modulus
Clay soil
Waste

ABSTRACT

Seeking to address large-scale issues faced by many countries today, such as excessive energy consumption, global warming, and uncontrolled mining activities, this research repurposes clayey mining and excavation waste to design soil-cement mixtures for road construction. A total of 2026 data points from laboratory experimental tests were statistically analyzed using regression models and neural networks to evaluate the effect of curing temperature on compressive strength, indirect tensile strength, and resilient modulus. The study focused on three types of clayey waste mixed with high early-strength hydraulic cement (Type 1 Portland cement) after 7 days of curing. The samples were cured in three different chambers, each maintaining a constant temperature of 10, 28, and 40 °C for 7 days, simulating the most common road temperatures in Colombia. Results showed that temperature has a positive effect of 18 % on the resilient modulus, which could lead to cement savings in warm climates. Additionally, an artificial neural network model was developed, which can contribute to the construction and design of more sustainable and environmentally friendly geothermal pavements. The use of these models and networks not only facilitates the study of multiple variables but also optimizes materials and methods, aiming to reduce energy consumption and costs.

1. Introduction

The Sustainable Development Goals 2023 Report highlights new challenges in terms of infrastructure [1]. In 2022, only 51.6 % of the world's urban population had access to public transport. Particularly in developed countries, people have more than one transportation option, while in the poorest developed countries people lack access to roads despite increasing demand for mobility. On the other hand, global consumption of raw materials has increased by 66 % since the 1970s, resulting in a per capita material footprint of 95.9 billion metric tons.

To ensure the efficiency and competitiveness of the transport sector, greener construction materials are being evaluated. These materials reduce the exploitation of virgin aggregates by using construction and demolition waste or recycled materials instead [2,3]. The performance and durability of pavement structures depend on the quality of the subgrade. For this reason, publications focus on the characterization of pavement materials, subgrade, granular layers, and asphalt mixtures through repeated triaxial load testing [4].

For this reason, research on soil resilience have significantly increased over the last 10 years. The publications aimed at establishing mathematical models for predicting resilient modulus pavements have grown exponentially. As shown in Fig. 1, the last 10 years 3806 publications research on resilient soil modulus, 607 focus on resilient module pavements, and eighty-seven address resilient modulus prediction models for subgrades, for a total of 4500 documents in 10 years.

From these documents, 75 % are research articles, 10 % are review articles, 10 % are book chapters, 2 % are part of encyclopedias, 2 % are short communications, and the remaining 1 % are papers, see Fig. 2. These statistical data align with reports from the United Nations, which clearly outline the needs regarding the exploitation of non-renewable

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https://doi.org/10.1016/j.conbuildmat.2025.140376
Received 15 October 2024; Received in revised form 3 February 2025; Accepted 7 February 2025
Available online 12 February 2025
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