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Real scale evaluation of vibration mitigation of sub-ballast layers with added tyre-derived aggregate

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HIGHLIGHTS

- Tyre derived aggregates can be mixed with the subballast layer under railway tracks.
- In field tests, added rubber reduces mean acceleration peaks.
- Adding TDA yields insertion losses between 0 and 10 Hz and over 50 Hz.
- On the other hand, there is a slight increase in the 10–50 Hz bandwidth.

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ABSTRACT

This paper represents a final stage in the assessment of granular sub-ballast materials mixed with tyre-derived aggregate (TDA) without binder material. The objective is to evaluate such mixtures through a full-scale test under real traffic conditions. An experimental track with three 30-metre long sections was constructed: one section was built with conventional sub-ballast; and the other two sections were built with mixtures containing increasing rubber content. This track was then monitored using accelerometers.

The results show a clear reduction in the acceleration peaks as rubber content increases. Moreover, the excited frequency bandwidth tends to become narrower and shifts to lower frequencies.

1. Introduction

Scrap tyres are one of the most troublesome waste materials generated by modern societies. They are highly flammable, not biodegradable, and their composition may cause toxic leaching if stockpiled, or hazardous fumes if incinerated [1]. Every year more than three million tonnes of scrap tyres are disposed of only in Europe [2].

One of the most promising alternatives to deal with scrap tyres is to use them as construction material for large infrastructures such as roads and railways. Within this framework, the authors propose mixing tyre-derived aggregates (TDA) from scrap tyres with coarse aggregates to build the sub-ballast layer of new railway tracks, hence enabling the disposal of large quantities of such a problematic waste product.

Over the past 30 years there have been a numerous applications for TDA in civil engineering, particularly in road and railway engineering. However, the vast majority of such applications took the form of rubber-only layers in road embankments [3,4], and bituminous mixtures with added rubber in slab tracks [5]. Focusing on railways engineering, there has been increasing interest in using scrap tyres when building new railway tracks, not only as a way of reusing a problematic waste material but also to provide benefits in the form of vibration alleviation. Most of this past research, however, has focused on rubber-sand mixtures [6], rubber-only layers [7,8], or attenuation elements made of scrap tyres such as under sleeper pads [9,10]. Other authors recently studied the performance of ballast mixed with rubber particles [11,12] and found that adding 10% crumb rubber (by volume) to the ballast could

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reduce degradation and increase energy dissipation [13]. A thorough review on design and maintenance technologies for reducing ballast deterioration found some techniques based on adding rubber particles from scrap tyres to be particularly useful, although some concerns regarding costs and increased settlement were also indicated [14].

However, unbound mixtures such as the ones proposed in this paper (i.e. rubber and coarse aggregates) represent a new approach to the problem. More specifically, using such mixtures as a sub-ballast layer (instead of a rubber-only layer) is a relatively unexplored field of research that has only been indirectly studied with laboratory tests and computer modelling [15].

The aim of this research is to assess the potential use of unbound rubber-aggregate mixtures as sub-ballast layers. As a first step [16], the behaviour of these mixtures was studied through an extensive set of laboratory tests in order to characterise them and measure the main features required for sub-ballast materials by Spanish and international railway regulations (including resistance to degradation, bearing capacity, resilient modulus, etc.). The results obtained showed that adding between 1 and 10% of rubber particles to the mixture (in terms of weight) improves resistance to degradation (measured using the Los Angeles and Micro-Deval coefficients) and reduces bearing capacity. An addition of rubber limited to 5% provided an optimum balance between these two features [16]. These results were further tested on a small-scale experimental railway platform. Bearing capacity and the long-term deformation of these new mixtures were analysed in the laboratory, as well as on the aforementioned experimental platform [17], as these are key factors in the life cycle and maintenance needs of any railway track.

As a third step of research [18], the potential vibration attenuation provided by the rubber-aggregate mixtures was tested – once again both in the laboratory and on the experimental platform. Vibration generated by passing trains and transmitted to the environment is one of the main issues that may hamper the development of railways, particularly in urban areas, as shown by extensive research, both theoretical [19,20] and practical [21,22]. Authors have paid attention to different damping materials and techniques, including elastic mattresses [23], open and filled trenches [24], or layers made of tyre shreds [25], with somewhat irregular results.

The results obtained for vibration attenuation of the proposed mixtures show that adding up to 5% of rubber increases the damping ratio of the material and reduces the observed acceleration peak registered at one metre from the excitation source [18].

The new mixtures have been evaluated in the laboratory under carefully controlled conditions, as well as using an *ad hoc* experimental railway platform. The next step in this research, and the specific objective of this paper, is to assess the performance of the new mixtures (and particularly their behaviour with vibration) in a real railway track under real traffic conditions. Accordingly, 2.5% and 5.0% mixtures were used as sub-ballast in two sections of a new railway track built as part of the renovation of the marshalling yard at San Roque Station near Algeciras (southern Spain). The new track was then monitored to measure the vibration transmitted to the environment by passing locomotives and to compare the behaviour of the new track with respect to a section built with conventional sub-ballast material.

The paper is organised as follows: first, the testing setting is described, including the construction of the new track and the installation of the monitoring devices. The monitored data is then shown, thoroughly analysed, and discussed. Finally, the main conclusions are given.

Fig. 1. Experimental track location.