Construction and Building Materials 101 (2015) 338–346

Contents lists available at ScienceDirect

Construction and Building Materials

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

Advanced characterisation of bituminous sub-ballast for its application in railway tracks: The influence of temperature

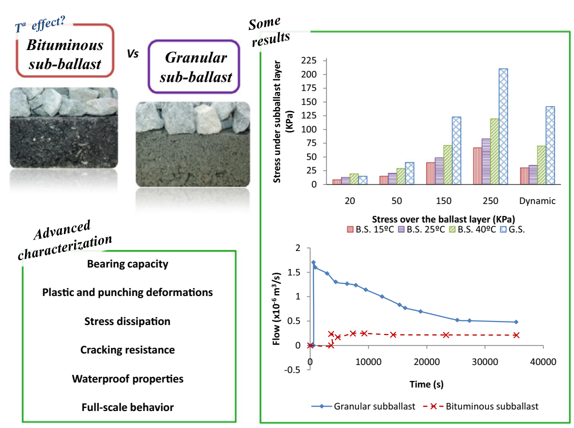
M. Sol-Sánchez, L. Pirozzolo, F. Moreno-Navarro, M.C. Rubio-Gámez *

Construction Engineering Laboratory of the University of Granada, Granada, Spain

HIGHLIGHTS

- Bituminous sub-ballast has been characterised under service life temperature.
- A full scale test evaluated the sub-ballast under different load conditions.
- Bituminous sub-ballast improves the mechanical response of the track.
- Bituminous sub-ballast exhibits higher strength against the trains loads.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 June 2015
Received in revised form 8 September 2015
Accepted 17 October 2015

Keywords:
Railway
Bituminous sub-ballast
Mechanical behaviour
Temperature effect

ABSTRACT

The use of bituminous sub-ballast in railway tracks is regarded as an appropriate solution for improving the strength of the section. However, for its widespread application, more in-depth studies are needed to assess its efficacy with respect to the main requirements that this material must meet under various service conditions. Such conditions include the range of temperatures that can occur during the service life of the railway tracks, which can modify the behaviour of bituminous material. This paper therefore focuses on evaluating the mechanical behaviour of bituminous material (under both routine and adverse temperatures that are expected in railway lines in extreme climates) in comparison to that presented by conventional granular sub-ballast. In particular, performance is examined with respect to the main requirements that need to be met by these materials (resistance to plastic and punching deformations, bearing capacity, stress dissipation, cracking resistance, and waterproof properties) for their use in railway tracks. At the same time, their influence on the performance of the global section was assessed for both types of sub-ballast by means of a full-scale test. The results demonstrated that the use of bituminous sub-ballast could improve both the mechanical response of the track and the protection of the remainder of the track bed layers, since this material exhibited higher strength against the loads imposed by passing trains, lower permeability, and a higher capacity to dissipate stresses transmitted by the ballast to the substructure. However, it is also important to consider that temperature plays a fundamental role in the resistance of bituminous sub-ballast to plastic and punching deformations, whilst its resistance to cracking declines sharply at higher temperatures. This could limit its application in railway lines in regions where values of this parameter are expected to be higher than those commonly recorded for this layer.

© 2015 Elsevier Ltd. All rights reserved.

* Corresponding author.
E-mail address: mcrubio@ugr.es (M.C. Rubio-Gámez).

http://dx.doi.org/10.1016/j.conbuildmat.2015.10.102
0950-0618/© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Traditional ballasted tracks have been widely used in railway transportation all around the world. However, the development of high speed railway and the increase in the loading capacity of trains have led to the need for enhancing the track substructure by adding stiffer granular layers (one of them being known as sub-ballast) between the subgrade and the ballast, with the aim of lengthening the service life of the track and reducing its maintenance costs. Nonetheless, this solution may require excessively thick granular layers in order to meet the minimum bearing capacity required, and therefore, significant consumption of high quality aggregates is needed. Thus, to reduce the thickness of sub-layers and to limit the deterioration of the track geometry to a minimum, an alternative solution consists of the application of hot-mix asphalt, material commonly used in other infrastructures like road pavements [14], between the ballast and subgrade to replace part of the conventional granular layers, a material known as bituminous sub-ballast [21,18].

Bituminous sub-ballast has been widely used in a number of railway lines (particularly in high-speed railways) in countries such as the United States, Italy and Japan, whilst other instances of its use can be found in European countries such as Austria, France and Spain [21,18]. The asphalt layer is generally applied with a thickness of around 12–15 cm, and is composed of a dense-graded bituminous mixture with a maximum aggregate size of 22–25 mm [16]. The asphalt mixture is generally designed with the same characteristic as that used in highways, although for its application as sub-ballast the bitumen content is increased by 0.5% in reference to the optimum for highways. Furthermore, the air void percentage is reduced to 1–3% in order to be used as an impermeable layer that can also avoid rutting problems, since the pressure is applied through the ballast over a wide area [18].

From an investment/cost viewpoint, it has been demonstrated that the use of bituminous sub-ballast is more appropriate than granular material when transport distances from the quarry are higher than 60–80 km, although the cost of granular sub-ballast is highly dependent on the local availability of quarries with materials that are suitable for meeting high-speed track standards [2]. In addition, it has also been demonstrated that the application of bituminous sub-ballast generally allows for a more homogenous behaviour of the track [2] whilst registering lower acceleration levels of vibrations [8]. However, before proceeding with the widespread application of this system, studies concerning the short and long-term efficacy of bituminous sub-ballast are needed to confirm that the main requirements of service can be met (mainly impermeability, bearing capacity, stress dissipation and durability) under the various service conditions expected during its application in railway tracks. In addition, it is important to consider that temperature variations cause changes in the performance of asphalt mixtures (more elastic at low temperatures and more viscous at higher temperatures) [4]. Thus, the benefits of using bituminous sub-ballast could depend on the temperature of service, which is subject to considerable variations, particularly in regions with extreme climates such as desert areas.

The present paper therefore focuses on the analysis of the mechanical behaviour of bituminous sub-ballast under various conditions that are expected to produce failure of the material, whilst also examining the influence of temperature on its performance. As a reference to evaluate the response of the bituminous material, the behaviour of conventional granular sub-ballast commonly used in railway tracks was also analysed. Thus, an in-depth study was conducted in order to examine the feasibility of using bituminous sub-ballast under a range of conditions of service (including adverse climate conditions) in reference to granular sub-ballast. The main properties studied for both materials (granular and bituminous sub-ballast) were resistance to plastic and punching deformations, bearing capacity, stress dissipation, and waterproofing properties. In addition, resistance to cracking was measured for the bituminous material, since this characteristic is fundamental in ensuring its durability. Finally, the effect of both types of sub-ballast on the performance of railway sections was assessed in the laboratory by means of a full-scale testing box.

2. Methodology

2.1. Materials

During this study, two main materials were utilised: granular sub-ballast; and asphalt mixture to be used as sub-ballast in railway tracks. The conventional sub-ballast analysed is commonly applied in Spanish high-speed railway tracks, sourced from Cerro Sillado quarry, in Guadix, Spain. This type of sub-ballast was composed of ophite aggregates with a continuous granulometry from 40 mm to 0.063 mm, as shown in Table 1. In addition, the granular material presented appropriate physical and mechanical properties for its utilisation as sub-ballast according to the Spanish Standard [20]. In addition to the properties listed in Table 1, its maximum density (2.73 g/cm^3) and optimal moisture (5.28%) were calculated by using the proctor test (UNE-EN 103-500) in order to obtain an adequate compaction of this material for its application in railway tracks.

The asphalt layer studied as sub-ballast was a dense-grade mixture type AC22S (UNE-EN 13108-1:2007) with a maximum size of aggregates equal to 22 mm. This material was manufactured using limestone aggregates and conventional bitumen type B50/70, whilst the filler was cement type CEM II/B-L 32.5 N. Table 2 lists the

Table 1
Main properties of ballast and sub-ballast.

Properties	Sieve (mm)	Standard	Ballast % passing	Sub-ballast % passing
Granulometry	*63*	EN 933-1:12	100	100
	50		85	100
	40		37	100
	31.5		8	100
	16		–	85
	8		–	66
	4		–	50
	2		–	30
	0.5		–	17
	0.2		–	14
	0.063		–	4.2
Content of fine particles (<0.5 mm) (%)		EN 933-1:12	0.08	–
Fines content (<0.063 mm) (%)		EN 933-1:12	0.03	–
Faces of fracture (%)		EN 933-5:99	100	100
Density (Mg/m^3)		EN 1097-6:01	3.24	3.24
Resistance to fragmentation (L.A.) (%)		EN 1097-2:10	5	14
Determination of particle shape – flakiness index (%)		EN 933-3:12	6	10
Sand equivalent (%)		EN 933-8:12	–	61

Download English Version:

https://daneshyari.com/en/article/256368

Download Persian Version:

https://daneshyari.com/article/256368

Daneshyari.com