Acoustic characterisation of railway tunnel portals

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The 78.5 km long, Bologna-Firenze High Speed railway runs in tunnels for 94% of its length. Knowledge on noise emission from railway tunnel portals is limited: thus, an experimental study aimed at verifying if and to which extent tunnel portals are a significant noise emission source has been necessary. The experimental campaign performed along the Firenze-Roma direct line has demonstrated that emissions are negligible when the High Speed or Intercity train runs inside the tunnel, while, during pass-by outside the tunnel, a reduction of 3 dB(A) Leq compared to fill sections was detected.

INTRODUCTION

The 78.5 km long, Bologna-Firenze High Speed (HS) railway runs in tunnels for 94% of its length. The studies on environmental noise impact, and the related noise abatement actions, have been aimed at the tracts running on fill or cut sections, on viaducts, and at tunnel portals.

Tunnel portals represent sound emission areas, whose characteristics do not fall into the standard types of sources treated by railway noise prediction codes, and for which the scientific literature [1,2], mainly addressed at road tunnels, proposes contrasting experimental data. It has therefore been necessary to:

a) Define if, and to which extent, the tunnel portal determines an increase of the sound pressure level compared to a fill section or viaduct (Phase 1).
b) Determine the sound power emitted by the tunnel portal (Phase 2a) and the vertical and horizontal radiation diagrams (Phase 2b).
c) Identify the best ways of simulating the source in a ray-tracing numerical simulation scheme (RAYNOISE code).

The experimental campaigns have been performed on the Firenze-Roma direct line (Galleria Castiglione, Viadotto Ascione), which is the only existing Italian railway infrastructure whose characteristics are similar to the future HS lines, and on which HS trains (such as the ETR 460 and ETR 500), as well as Intercity (IC) trains are presently in service.

EXPERIMENTAL CAMPAIGN

Phase 1 aims at determining the effect on sound level due to the presence of the tunnel. Measurements have been performed in 3 points at 3.5 m height above the track: P1, 25 m from the tunnel entrance, 25 m from the track axis; P2 and P5, on the axis of the fill and viaduct tracts, 25 m from the track. In this phase, synchronised audio recordings during 36 train pass-by have been performed.

In phase 2a, measurements have been made in the positions indicated in Figure 1. Points P1÷P4 lay on the semi-arch of radius 8.60 m, centred on the geometric axis of the tunnel shaft and subdivided into sectors of 16° angular aperture, 3.5 m from the tunnel entrance; points P5 and P6, 25 m from the entrance, 3.5 m and 25 m from the track axis, 1.5 m and 3.5 m height; P7, in the niche about 100 m from the entrance, the microphone flush with the tunnel inside lining, 1.5 m high. Synchronised audio recordings during 49 train pass-by have been performed.

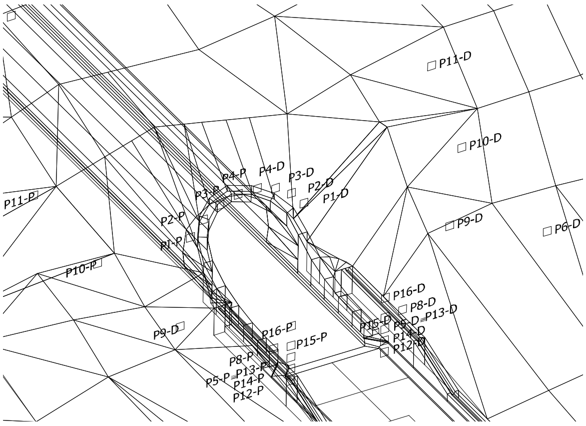

FIGURE 1. Position of the microphones

In phase 2b, measurements have been performed in points P8-P16 indicated in Figure 1. P8÷P11 are situated on a horizontal arch obtained by cutting a sphere of radius 25 m and centre coinciding with the centre of the tunnel entrance with a horizontal plane at +3.5 m height; the microphones cover a 71.1° arch;

P12÷P16 are situated on a vertical arch obtained by cutting a sphere of radius 25 m and centre coinciding with the centre of the tunnel entrance, with a vertical plane passing through the point 25 m from the tunnel entrance, at the minimum distance permitted by the tracks and the supply cables.; P7 is in the niche about 100 m from the tunnel entrance with the microphone flush with the tunnel inner lining 1.5 m height; synchronised audio recordings have been performed during 52 pass-by.

The analysis of the experimental results allow to conclude that, during pass-by of HS trains such as ETR500 and ETR460, fill section tracts emit on the average 2.3 dB(A) more than the tunnel portal, with a standard deviation of 0.86 dB(A). Such trend is confirmed by data of IC trains: fill section tracts emit on the average 2.5 dB(A) more than the tunnel portal, with a standard deviation of 1.6 dB(A).

These average values have been calculated taking into account recordings of HS and IC pass-by having a speed differential between the two measurement points respectively less than 5 km/h (HS) and 10 km/h (IC). The variance of the acoustic data associated to such speed ranges is of the order of ± 0.5 dB(A).

The HS trains are characterised by an average value of pass-by Leq (considering a Lmax – 20dB(A) cutoff level) of 86.6 dB(A) in front of the portal and 87.2 dB(A) in front of the fill section.. Spectral analyses confirm the presence of very low frequency components near the portal, of negligible significance in relation to legislative limits compliance.

The analysis of synchronised multiple spectra furthermore indicates that the SEL measured with the train outside the tunnel practically coincides (with differences of 0.2 dB(A) for HS and 0.3-0.4 dB(A) for IC trains) with the pass-by SEL. The fact that the portal is a negligible emission source is confirmed by the fact that the difference between the SEL values when the train is outside and inside the tunnel is about 14 dB(A) for HS and 11-12 dB(A) for IC trains.

NUMERICAL ANALYSIS

In order to extend the field results to the tunnel entrances that are present along the Bologna-Firenze tract, a technique capable of reproducing the measured sound field has been applied. Such technique is based on the ISO 9613 standard, i.e. on the concept that the environment acts as a transfer function between the sound sources and the microphones used for the field measurements. The unknown sound power values have been determined with a numerical model of the area facing the tunnel entrance, based on he Raynoise numerical simulation code, starting from the measured sound pressure levels.

The numerical scheme of the tunnel portal has been determined through trial simulations aimed at identifying the system of sources that best fits the objective of reproducing with an adequate degree of accuracy the sound field emitted by trains passing inside the tunnel.

The acoustic modeling of HS and IC trains that best fits the experimental data, for trains entering the tunnel, consists of one omnidirectional point source situated at the entrance section, in correspondance of the track axis 4 m above the track level, plus one directional point source (directivity angle of 30° with respect to the horizontal and vertical planes) on the axis of the opposite track, still on the entrance plane at 4 m height. Figure 2 shows the simulation of the acoustic field in proximity of the tunnel entrance during a HS train pass-by.

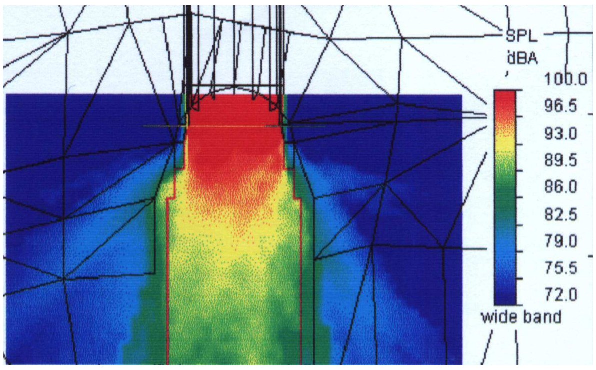

FIGURE 2. SEL for HS train entering the tunnel

For trains coming out of the tunnel, the emission sources consist of one omnidirectional point source situated at the entrance section, in correspondence of the track axis 4 m above the track level, plus one directional point source (directivity angle of 30° with respect to the horizontal and vertical planes) on the axis of the opposite track, still on the entrance plane at 4 m height.

Comparison between measured and simulated data show an overestimate of the model of 0.1 – 2 dB(A); only at some points near diffraction edges or remote from the entrance plane the differences reach 3 - 4 dB(A).

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