Analysis of Tram-induced Vibrations Affecting Roads and Buildings in Standard Urban Sites

Cristina Pronello[†]

Polytechnic University of Turin, Department of Hydraulics, Transport and Civil Infrastructures, Corso Duca degli Abruzzi, 24, 10129 Turin, Italy

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The passage of trams in towns and cities can cause considerable disturbance to people living or working on streets with tramways. This study investigates the impact of tram-induced vibrations in streets with different arrangements, i.e. different road layout and building types, and measured at varying distances from and heights above the tram lines. The first step involved the definition of a methodology for choosing test sites and defining ways of measuring the vibrations. In the second step, a series of measurements was made in order to compile a database which could provide initial indications regarding the impact of vibrations on different types of site and buildings. These results enabled the planning of a new series of in situ measurements using the proposed methodology, as well as a programme of measurements to be carried out in laboratory conditions in order to study the effects of wheel and track conditions on vibration.

[†] Member of the International Institute of Acoustics and Vibration (IIAV)

1. INTRODUCTION

In towns and cities which have tramway networks, the complaints received about the problem of noise and vibration have led the authorities to search for ways of alleviating the problem. While numerous studies have been made of the noise and vibration caused by railways, very little research has been carried out on similar problems caused by trams. Although the concept of the two transport systems is similar, there are significant differences in terms of:

- infrastructure: tramways are also located along roadways shared with other traffic and not dedicated lines;
- vehicles: the very different mass and length of the vehicles;
- speed: the speed of trams is normally much lower, since they circulate within urban areas.

In the case of tramways, a further element of complexity is caused by the fact that often limited knowledge is available on the 'substructure' below the road or pavement, making it far more difficult to predict the effects of propagation of the vibrations. Since railways generally have a 'free field' along the line and no substructures, the propagation of vibrations is easier to analyse.

One way of investigating the propagation of vibrations and predicting the effects on buildings without incurring huge expense is to build an empirical model based on in situ measurements. This approach has already been adopted in other studies[1], where a semi-empirical regression model was built using a data base of measurements of vibration and structure-borne noise emissions. Similar approaches have been followed in other studies of vibrations induced in buildings by trains[2] and by underground lines[3] running in tunnels.

2. OBJECTIVES OF THIS STUDY

The aim of the present study is to define an empirical model able to predict tram-induced vibrations on roadways and inside buildings. The approach followed, however, differs from the studies mentioned above. Here, the objective was to establish whether it is possible to define "clusters" of sites in which the vibration effects can be predicted. To do this it was necessary to classify the sites (i.e. streets with tramways) in terms of the variables likely to influence the propagation of vibrations (i.e. type of infrastructure, site configuration, building shape, etc.). This was then 'crossed' with another classification based on the variables influencing the source of vibrations (the vehicles themselves).

A cross-classification would make it possible to identify clusters with similar vibration levels. Every cluster would therefore have a specific model characterised by variables defined as a function of the results of in situ measurements.

After defining the methodology, a brief survey was carried out to verify the feasibility of compiling a database to contain the recorded data according to site type. The results obtained have been analysed and a first simple regression model produced.

3. THE METHODOLOGY

The definition of parameters linked to sources and propagation of vibration was established through the following steps:

- identification of significant variables;
- definition of a standard procedure for choosing the points of measurement and ways of making measurements in order to obtain comparable data;
- building of a database using in situ measurements.

This approach has already demonstrated good results for rail transport[4] and road transport[5-7].

3.1. Definition of Variables

Although the source of vibration is the passage of trams, the level of disturbance for people living or working near tramway lines is not simply defined by the sum of single passages or characterisation of the source. The real impact depends on the local conditions, i.e. the detailed characteristics