

Noise and Vibration—an Obstacle for Underground Construction?

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Abstract—Although ground vibrations have been studied extensively for a number of years, acceptable levels of vibrations vary from country to country. In 1985, the International Tunnelling Association's Working Group on Research undertook a study to analyze the standards applied in different countries as a first step in preparing a state-of-the-art report on the effects of noise and vibrations resulting from construction on the surrounding environment, structures and equipment, and human beings. The results of the ITA's questionnaire survey on this topic are presented herein.

Résumé—Bien que les vibrations du sol aient été étudiées largement depuis de nombreuses années, les niveaux admissibles de vibrations varient d'un pays à l'autre. En 1985, le groupe de travail sur la Recherche de l'AITES a entrepris une étude des normes utilisées dans différents pays. Cette analyse est en premier pas dans la préparation d'un rapport sur les effets des vibrations et des bruits de chantier de construction sur l'environnement, les structures, les équipements et les êtres humains alentours. Les résultats du questionnaire de l'AITES sur ce sujet sont présentés ici.

As technical development in a modern, industrialized society has come to involve more and more structures being built both above ground and underground with bigger and heavier machines, vibrations of different kinds have become an environmental problem.

Vibrations in the air—normally referred to as "noise"—have been carefully studied and today many countries have established regulations and recommendations for limiting noise under various conditions.

Vibrations in the ground, primarily those caused by blasting and piling, have also been the subject of extensive investigations over a number of years. In many countries, however, opinions differ with regard to the effect of these types of vibrations on human beings, buildings, machines, and other structures. Therefore, different norms or accepted levels of ground vibrations are applied in different countries.

This finding is very evident in the responses to a questionnaire survey submitted to the ITA Working Group on Research, which raised this topic for analysis a few years ago. The responses obtained from this questionnaire are summarized below.

Today, predictions of expected vibrations at a planned construction work-site and the eventual effects on people and buildings are most contro-

versial. This situation often results in considerable limitation of the blasting work, which can increase the contractor's difficulties.

The responses to the ITA questionnaire also clearly reflected a desire for international cooperation in this field, in order to achieve an international understanding regarding vibration recommendations.

Another valuable result of the ITA enquiry was that through the questionnaire, the Working Group became aware of a comprehensive research work that has been carried out by Dr. Barry M. New at the Transport and Road Research Laboratory (TRRL) in Crowthorne, Berkshire, U.K. The Working Group found Dr. New's work well worth a wider audience within the international tunnelling community and has, therefore, chosen to publish, in abbreviated form and with the permission of the author, the results of TRRL Research Report 53, "Ground Vibration Caused by Civil Engineering Works," as an extension to this report.

The ITA's Questionnaire on Vibrations During Construction

At the 1985 meeting of the ITA's Working Group on Research, Sweden accepted the responsibility for initiating a state-of-the-art report on vibrations during construction and their effects on the surrounding environment, on structures and equipment, and on human beings.

A survey questionnaire comprising questions on the current status of legislation/recommendations for noise and vibration levels, as well as ongoing or planned research in this field, was

sent to ITA member countries. Sixteen countries responded to the survey.

Unfortunately, the information obtained was not as comprehensive as the Working Group had hoped for. This might imply that there is a need for an exchange of knowledge among the countries, as well as a need for more research work in the field.

The Working Group's research was aimed at summarizing the status of the selected field of interest (i.e., noise and vibrations during construction works), emphasizing problems and pointing out promising lines for research activities, keeping the general goal in clear view—namely, to remove irrelevant obstacles that may hinder the optimal use of underground solutions in a developing society.

Why Study Noise and Vibration?

In general, increasing attention has been given to all kinds of environmental disturbance, as a consequence of our mutual goal of a "higher quality of life." However, this desire for improved quality of life often leads to conflicts of various sorts. In a typical situation, the technicians cannot see any problems with a particular construction method or structure, while other groups of people worry and react in unexpected or "irrelevant" ways to the proposed construction.

In the case of vibrations from blasting, the physical effects of the act are normally very slight; however, people often become anxious if they are not well informed in advance, or when they cannot be or are not provided with a good motivation to accept some temporary disturbance.

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Authorities working with regulations need a good body of knowledge and experience in order to be able to determine reasonable limits for vibration levels. They have to choose which parameters are relevant to the impact of vibrations on structures and human beings.

Aim and Scope of the ITA Study

In order to limit the subject, the Working Group began by excluding effects that occur throughout the life of an underground structure, and concentrated instead on the problem of vibrations occurring during construction, and the effects of these vibrations on the surrounding environment, structures and equipment, and human beings.

The aim of this first enquiry was to map and briefly describe the situation in various countries in order to identify similarities and differences in the attitudes of planners and builders, as well as lay people and authorities, to problems associated with noise and vibrations during construction works.

Evaluation of Responses to the ITA's Questionnaire on Noise and Vibrations

Replies to the questionnaire developed by the ITA Working Group on Research were received from the following ITA member nations: Australia, Austria, Czechoslovakia, Denmark, Egypt, Finland, West Germany, Iceland, Japan, Mexico, The Netherlands, Norway, Poland, South Africa, Spain, and the United Kingdom. Below are some of the questions the survey asked concerning noise and vibrations during construction, and a summary of the responses.

1. *Are vibrations during underground construction work considered to be a problem in your country?*

Noise and vibrations during underground construction seem to be a problem in most countries. The only country that did not report this kind of problem is Iceland, where all underground construction to date has taken place in remote areas.

2. *Are there any national standards or regulations for noise and vibrations in your country?*

Nearly every country reported having some national standards or regulations for vibration levels. Only Finland and Mexico appeared to lack such standards.

Some countries had regulations for other parameters in connection with this type of disturbance. Typical parameters were working-hour regulations, noise contamination, and vibration velocity. In Mexico, the only regulations pertained to noise contamination, which is restricted to 75–80 dB.

3. *What is the basis for current regulations?*

The basis for current regulations varied for the different countries. The

answers could be divided into two groups. The first group comprised countries that based their regulations on their own experience and research

Table 1. Groups currently performing research in the field of noise and vibration.

Country	Research Group
Australia	CSIRO, ICI, JKMRC
Austria	Zentralanstalt für Meteorologie und Geodynamik University of Vienna, Applied Geophysics Division, Hohe Warte 38, A-1190 Wien, Austria
Czechoslovakia	VUIS Bratislava—The Research Institute of Civil Engineering, Botanicka 68A, Brno, Czechoslovakia The Technical University of Prague, Solinova Str. 7, 166 08 Prague, Czechoslovakia
Denmark	Skandinavisk Lydteknik A/S, Granskoven 8, 2600 Glostrup, Denmark
Egypt	Scientific Research Academy
Japan	The Acoustical Society of Japan, The Institute of Noise Control Engineering of Japan
Mexico	Institute of Geology and Institute of Geophysics at the National University Institute of Polytechnics, Tecnológico de Monterrey Petroleos Mexicanos ICA Foundation
Netherlands	Delft Geotechnics, P.O. Box 69, 2600 AB Delft, Holland TNO-IBBC (Rijswijk)
Norway	Norwegian Geotechnical Institute
Poland	Central Mining Institute (Katowice) Technical University (Krakow) Institute for Occupational Safety (Warszawa) Institute for Structural Technology (Warszawa)
South Africa	Bernard Price Institute of Geophysical Research, Johannesburg
Sweden	Swedish Detonic Research Foundation (SveDeFo)
United Kingdom	Transport and Road Research Laboratory, Crowthorne, Berkshire, RG11 6AU, U.K.

work. The second group had simply adopted regulations and recommendations from other countries.

4. *What are the normal methods of monitoring vibration levels in your country?*

The normal method reported for monitoring vibrations caused by construction projects is measuring the peak particle velocity (PPV). In about half of the countries responding to the survey, the vibration measurements are completed with the registration of frequencies. In just a few countries, a complete measurement is carried out, including peak particle displacement and particle acceleration.

5. *Is any research in this field currently being performed in your country, and if so, who is performing and financing these studies?*

All but one country (Iceland) reported that there were ongoing research

programs in the field of noise and vibration during construction works. Table 1 lists the organizations performing this research. The research work is being performed by universities, institutions and some private companies. Usually the studies are financed by the government.

6. *What are your views on the need for further research and international cooperation?*

Because blasting and piling seem to be more common in densely populated areas, there is a great need to predict the degree of vibrations for all kinds of construction and to calculate the levels that cause problems in different situations. In conjunction with these research needs, further research was recommended to study the propagation and evaluation of vibrations from blasting and piling. The problem with noise associated with construction

works near buildings was considered another item requiring further research.

Respondents indicated that international cooperation is needed in the field of vibration and noise related to underground work. Many respondents stressed that practice and experience must be taken into consideration when establishing new standards for noise and vibration during construction.

Cooperative international research efforts, to be performed, for example, by ISO, ITA, ISRM, and EEC, were suggested by countries responding to the questionnaire.

The extension of this report, published on the following pages, has been adapted from British TRRL Research Report 53, "Ground Vibration Caused by Civil Engineering Works," by Dr. Barry M. New. □