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Fixed noise monitoring network for the S.Ruffillo-Savena-Rastignano construction site of the Bologna-Firenze High Speed Railway

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This paper describes the fixed noise monitoring network, installed in the early months of 2001 near the *S. Ruffillo-Savena-Rastignano* construction site of the Bologna-Firenze high speed railway line, to monitor the periods of construction (five years) and pre-exercise of the railway. The network includes five fixed microphones for continuous data acquisition, an automatic sensor calibration system and a weather data acquisition unit. The stored data are analysed weekly to obtain aggregated noise descriptors. The measured indices permit a constant control of the trend of noise impact determined by the construction site, in comparison with the legal limits. The presence of personnel devoted to the network management allows, if necessary, the rapid adoption of corrective measures, such as the enforcement of emergency procedures to reduce noise emission - either of technical (e.g., the installation of mobile or fixed noise barriers) or management nature. The effectiveness of the adopted measures is verified *ex-post* by analysing the data collected by the monitoring network. This system represents the first practical example in Italy of a continuous noise monitoring system aimed at the control and management of noise impact due to the construction and exercise of a primary public transportation infrastructure.

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1. INTRODUCTION

The *S. Ruffillo-Savena-Rastignano* construction site is one of the most critical areas, from the environmental standpoint, of the new Italian high-speed railway network. The area is situated in the Bologna municipality, near the intersection between the Bologna-Firenze high speed line and the Bologna urban tract. The environmental problems are primarily linked to the presence of a highly urbanized context, but with morphological, geological and naturalistic peculiarities that are typical of the adjacent *Appennino Tosco-Emiliano* mountain range; such characteristics require specific cautions and imply severe technical difficulties in conducting the works, particularly where tunnel excavation is concerned. The sensitivity of the environment, the complexity of the context and of the existing sound sources, the necessity of acquiring data useful for an effective environmental management of the construction site and for a precise information to the local communities interested by the works, have induced the local administrations to require the installation of a fixed noise monitoring network that will operate through the period of construction (five years) and of pre-exercise of the new railway line.
The installation of the network - which has been fully supported by TAV (the Italian Railways company responsible for the project) - has been completed in the early months of 2001 by Fiatengineering, with the assistance of acoustic advisors, on behalf of the CAVET consortium, which is responsible for the railway line construction. Noise monitoring in the areas interested by the construction site represents, in the pre-construction phase, a tool for determining the present acoustic quality level, the respect of legal noise limits and the identification of critical situations, while during construction will permits to monitor the time trend of the acoustic descriptors and the effectiveness of preventive and corrective noise control measures.

2. MAIN FEATURES OF THE MONITORING NETWORK

The *Bologna S. Ruffillo* noise monitoring network consists of five data collection units installed in proximity of the residential receptors assumed as control points for the population exposure to noise determined by the construction site activities. At the center of the monitoring area, a weather data acquisition unit - capable of continuously acquiring wind speed and direction, air temperature and relative humidity, barometric pressure, and precipitation - has been installed. Each unit includes:

- Water-proof cabinet equipped with thermostat-controlled electric heater;
- Microphone system suitable for outdoor installation, equipped with internal reference signal generator for calibration of the entire measurement chain;
- Real time sound analyzer;
- Palmtop PC equipped with flash memory card for data storage.

The main features of each of the five units are summarized in Table 1.

Table 1: *Characteristics of the data collection units*

Point	Instrumentation
RUC-BO-02 RUC-BO-05 RUC-BO-06 RUC-SL-01	½” microphone LD 2541 with wind and bird protection Preamplifier LD 2101 Cabinet-microphone connecting cable for outdoor installation Sound analyser LD 820 Microphone calibrator LD CAL-200
RUC-BO-01	*As above, except*: Sound analyser LD 824

Each monitoring unit is powered from the grid at 220 V AC and is equipped with data storage capacity of about three weeks. Every two weeks the memory is reset and data are transferred to the flash memory card of the palmtop computer. The validation, filing and analysis of data is performed centrally at the Contractor’s headquarters on a desktop PC equipped with CD writer unit for data backup. The network is managed with the N&V Works software, suitable for processing data acquired with Larson Davis instrumentation. The software allows for real time interfacing with the analyzer; it performs calculation of overall / running L_{Aeq}, multiple masking, statistical analysis, identification and processing of individual acoustic events (such as train pass-by) as required by DPR 18/11/97 n. 457, plus several data management and editing functions.

Data are subject to a defined quality control procedure that may be summarized in the following steps. Data stored in the palmtop PC flash memory are first checked in order to identify possible malfunctioning of the data collection unit or chain calibration problems: data that are judged acceptable are transferred to the desktop PC. Weather conditions during data collection are then verified: measurements in presence of rain, snow, fog or strong wind (speed above 5 m/s) must be discarded and therefore the corresponding periods are masked from the time history.

The results are summarized on a weekly basis in order to produce two-week or monthly reports; long-term trends of the noise indicators are highlighted in the six-month or twelve-month environmental reports. All relevant information, including calibration controls, measured / calculated acoustic indicators, applicable legal limits, weather conditions, correlated construction site activities, etc., are specified in the reports.

3. ANALYSIS OF THE MONITORING DATA

An effective and quick evaluation of the acoustic climate in the area requires an analysis of the monitoring data which is repeated in time and based on a limited number of control indicators oriented to the respect of legal limits and to the control of population annoyance. In addition to the above goals, data aggregation permits an easier communication of the results and helps the management of emergency situations that may be identified. The actions adopted so far to reduce noise impact of the construction site, identified from the monitoring activity, have been primarily focused on reducing the emission of machinery and plants, and, when feasible, on organizing the construction activities in such a way to redistribute in space and time the noisy ones. Just as a second step, whenever the above mentioned measures proved to be inadequate to attain the mitigation goals, the installation of fixed or mobile barriers was considered. Monitoring of the post-intervention results has made possible the compilation of technical reports in which costs and benefits achieved with each of the applied measure are precisely quantified.

Table 2 summarizes the noise control indicators adopted in the monitoring, together with the applicable legal limit to be verified or action to be taken, based on the indicator's value:

- $L_{Aeq,TR}$: [A-weighted equivalent continuous SPL, Day (6-22) / Night (22-6) Reference Time]; represents, for each week, the maximum Day / Night L_{Aeq} value over the 7 day period;
- $L_{Aeq,TL}$: [A-weighted equivalent continuous SPL, Day (6-22) / Night (22-6) Reference Time]; represents, for each week, the average Day / Night L_{Aeq} value over the 7 day period;
- L_{Aeq,h_max}: [A-weighted equivalent continuous SPL, one hour]; represents, for each week, the maximum Day / Night hourly L_{Aeq} value, over the 7 day period.

Table 2: *Noise monitoring control indicators and their use*

Noise control indicator	Applicable legal limit (DPCM 14.11.97) / Action to be taken
$L_{Aeq,TR}$ (6-22) / $L_{Aeq,TR}$ (22-6)	▪ Attention limit Day / Night [60 / 50 dB(A)] with reference to the worst day of the week ▪ Occurrence over the week, based on weekly operation plan ▪ Complementary actions aimed at differential immission limit [+5 / +3 dB(A)] compliance
$L_{Aeq,TL}$ (6-22) / $L_{Aeq,TL}$ (22-6)	▪ Absolute noise immission limit Day / Night [60 / 50 dB(A)] with reference to the average weekly condition
L_{Aeq,h_max} (22-6)	▪ Nighttime hourly attention limit [70 / 55 dB(A)] ▪ Verify effects on sleep

The long-term (two years) time trends of the above noise control indicators, measured at position RUC-BO-06, are shown in Figures 1 and 2.

Figure 1 shows the absolute values of the above indicators; the time trends of the noise levels acquired by the five data collection units show similar long-term time trends, particularly with respect to the $L_{Aeq,TR}$ and $L_{Aeq,TL}$ indicators, which are calculated over relatively long integration times (16 hours for Day and 8 hours for Night), while a higher dispersion characterizes the hourly L_{Aeq,h_max} indicator.

Figure 2 shows the time trend of the differences of the above indicators with respect to the related legal limits indicated in Table 2. Superimposed on such trends, tendency lines calculated as moving averages on 26 weeks (6 months) are shown, which reveal a clear reduction of the impacts. Significant noise reduction corresponding to the summer and Christmas holiday periods are also clearly visible. A more detailed analysis allows to identify three distinct phases, directly correlated with the construction plans.

The initial phase (extending through the summer of 2001), relative to the construction site start-up and to the completion of the open air structures, definitely implies the highest impact, particularly in the nighttime period. A transition phase follows through the end of the year, in which construction proceeds at full speed and the first measures aimed at noise reduction are adopted, such as a better management of the concrete production plant, equipped with a sound shielding tunnel, maintenance of the joints of the Bailey bridge on the *Savena* river, interdiction of heavy vehicle traffic during the night period, enforced following the repeated complaints of the local communities.

The following intermediate phase (winter 2002) is characterized by a significant and progressive reduction of the outdoors activities, following the interruption of the main tunnel front excavation. For the initial period activities are decreasing, due to the completion of the tunnel coatings and to the progressive elimination of the excavated material. The remaining part of the year (spring to end of 2002) is characterized by limited outdoors activity and limited operation of the tunnel ventilation plant.

The final phase, which follows the activity interruption at the end of 2002, shows a generalized increase of noise levels, as a consequence of the fact that tunnel front excavation has resumed and consequently activities on the outdoors areas have also increased. Noise has attained levels similar to those of the initial months of 2002 , but a further increase can be expected when the accumulation and disposal of excavated material will reach steady state condition.

4. CONCLUSIONS

This *Bologna S. Ruffillo* monitoring network represents the first practical example in Italy of a continuous noise monitoring system aimed at the control and management of noise impact due to the construction and exercise of a primary public transportation infrastructure. The noise data collected by the network have allowed to verify the impact of the High Speed railway construction site activities in relation to the evolution of the working phases and of the correction and mitigation measures adopted in the two years following the beginning of the activities. The network has also allowed to determine the time trend of the noise indicators and to interpret such trends with reference to the applicable legal limits.

It has been demonstrated that legal limits cannot always be fully respected, even adopting state of the art machinery and equipment. Careful planning and execution of the construction activities, as well as the information and training of the personnel, have however contributed to reducing the impact of intrinsically noisy activities. Moreover, the presence of a continuous monitoring system has promoted, among the local communities, a more favorable attitude towards the construction activities, thus limiting the protest actions that often take place in similar situations.

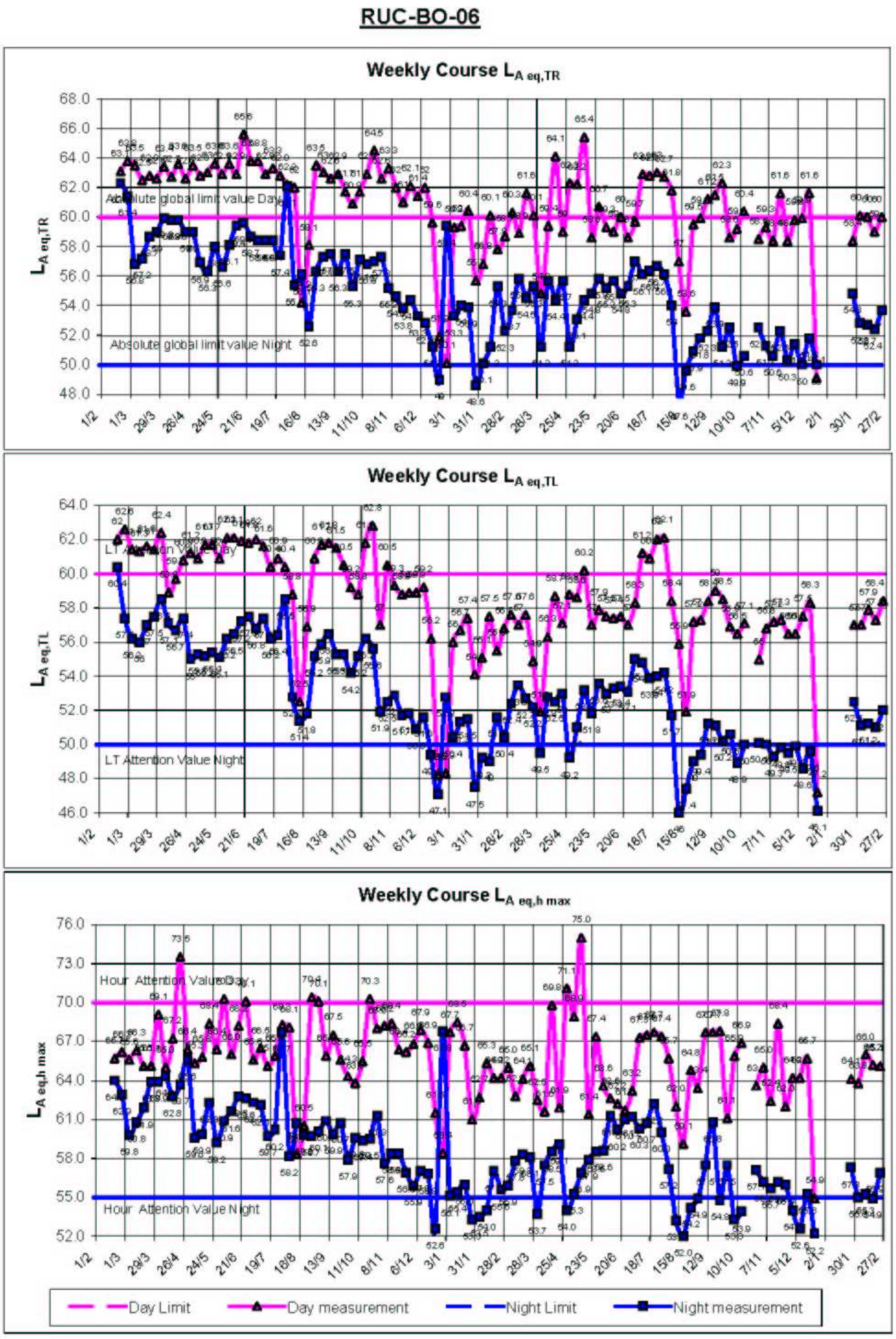

Figure 1. *Two-year trends of noise indicators*

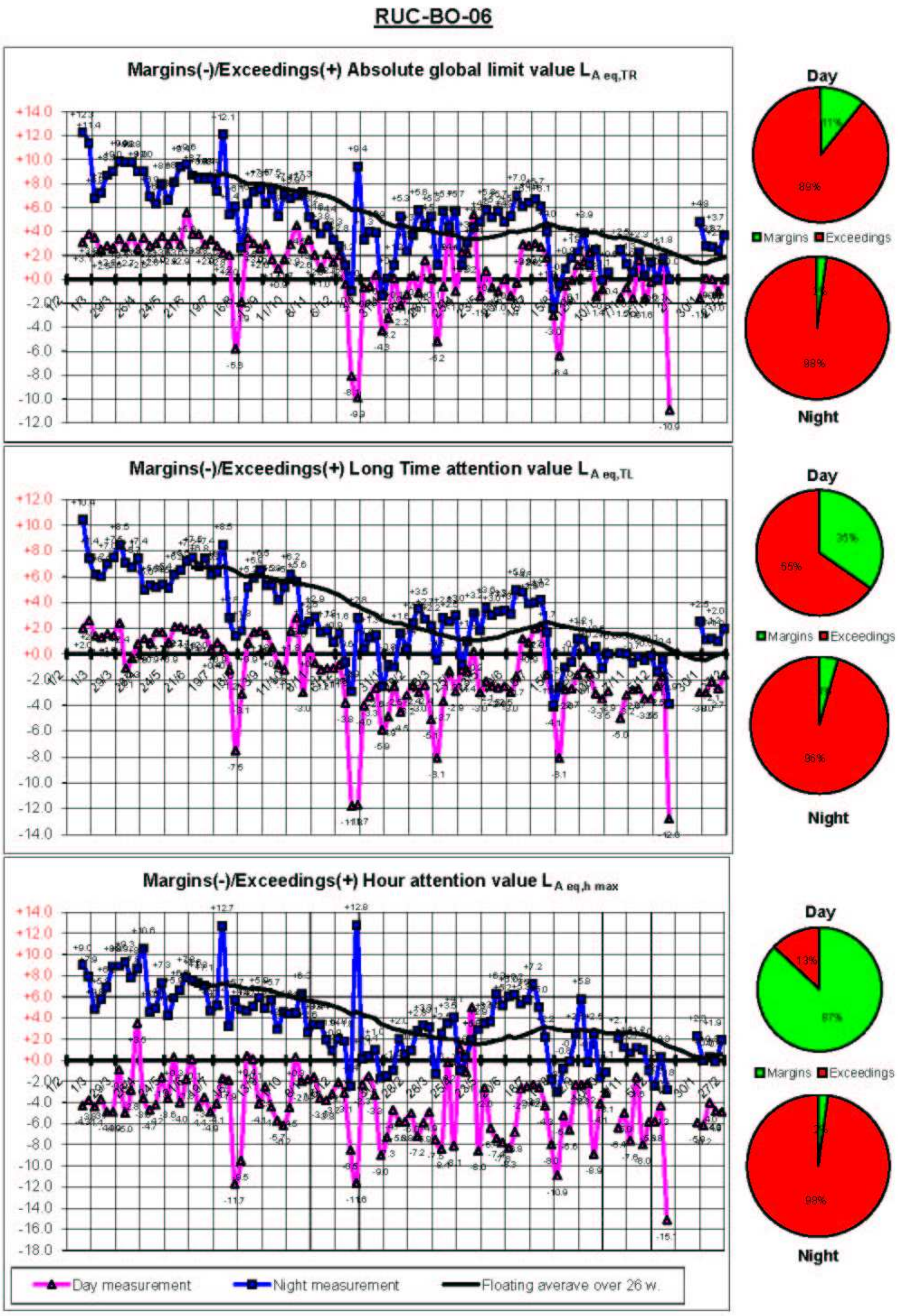

Figure 2. *Difference noise indicator – applicable legal limit*