HIGH SPEED TRAIN NOISE ABATMENT : IMPORTANT PARAMETERS AND CASE STUDY

J-P. CLAIRBOIS, P. HOUTAVE, E. WEYERS, V. TREFOIS

Acoustical Technologies
215 Av. Brugmann
1180 BRUSSELS — Tel. (32)2-344.85.85
BELGIUM — Fax. (32)2-346.20.99

ABSTRACT

In two previous papers [1], [2], we presented the validity of a method that calculates the L_{eq} values along High Speed Train (TGV in french) lines from the level/time evolution of moving trains. Thanks to this method, it is now possible to compute specific time-related effects such as interactions between train bodies and close obstacles.
This paper lists important parameters to be considered within TGV studies and presents the various levels of study, starting from the research of the best traject (extensive studies), passing through noise impact studies (intensive studies) of the chosen traject to the dimensionning of antinoise devices (final design), and all this to guarantee precise respect of noise criteria. A theoretical comparison study conducted on about 80 different types of antinoise devices including earthberms and noise barriers of different forms, dimensions and materials is also presented.
At last a "final design" study using all benefits of the method (full 3D and time representation) is presented.

1. LEVEL/TIME METHOD

L_{eq} values are commonly used to assess noise impact along railway lines. The reason for this is probably that this indicator is a quite complete one in regard with the annoyance. It includes the L_{max} of the event, its duration and the total number of passages during the period of concern. In [1] and [2] we presented the advantages and accuracy of the level/time method, calculating the L_{eq} values *simply* through the discretisation of the following formula :

$$L_{eq} = 10 * \log_{10}\left[\frac{1}{T}\int_0^T \int_0^L 10^{0.1*SPL(t,l)}\,dl\,dt\right]$$

where *T* is the period of integration, *L* the length of the train, *SPL(t,l)* the sound pressure level induced at *t* by an elementary line-source of train *dl*.

Thanks to a measurement survey over 150 passages of TGV, article [2] proved the ability of the method to accurately assess L_{eq} values. Developments of the method were directed to the full implementation of moving vehicules (considering movable sources instead of stationary ones), the interactions between barriers and train bodies and a better representativity of the radiated power.

2. IMPORTANT PARAMETERS

Assuming the emitted noise of High Speed Train in its direct vicinity is too high to be accepted, appropriate anti-noise devices need to be designed. The level of study is then of great importance in order to master the right definition of devices to be used and to guarantee the required efficiency. The relevant parameters are :

Radiated power : as described in [1] and [4] the pertinent way of measuring it makes use of the $L_{Aeq,tp}$, (figure 1) that is the equivalent A-weighted continuous level determined during the passage of a train. If we want to go further we can use the real level/time evolution averaged on a significant number of trains. This can be useful to separate, for example, the effect of engines and coaches.

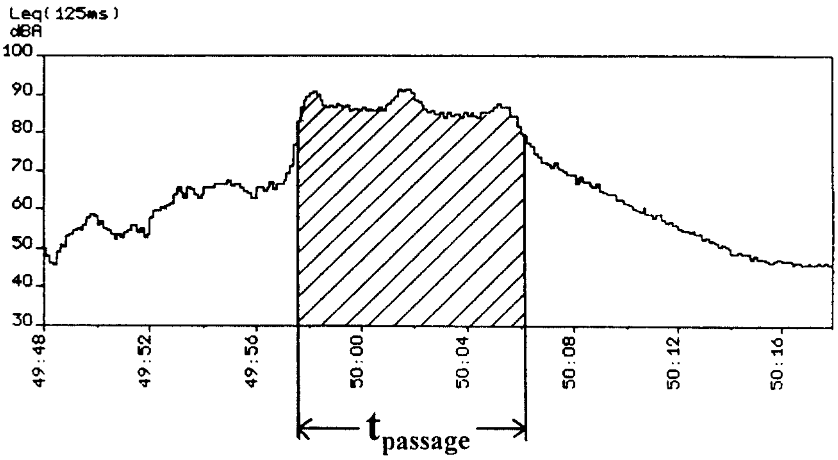

Figure 1 : Calculation of $L_{Aeq,tp}$.

Horizontal and vertical directivity patterns : these parameters are too often forgotten. Nevertheless vertical directivity interferes on the full propagation of noise not only in free-field but also in presence of close obstacles. Horizontal directivity however, is less important except if we want to retrace the real acoustic signature of the passing trains, for which the trail can be significant (trains passing in stations).

Speed, length and number of trains : these parameters directly condition the total duration of the event (speed, length) and the number of events, both integrated in global L_{eq} values used to assess the problem of noise. Especially the radiated power has to be known as accurately as possible for the whole range of speeds concerned. One can also note that the spectrum varies significantly with the speed of the train ([7] is an example of measurement survey used to qualify the radiated noise at different speeds).

Environment and obstacles to the propagation : obviously the global 3D environment has to be taken into account, what is already done in the actual classic noise prognoses. However the fact that the close environment can seriously interfere with the moving train is not yet considered enough. Obstacles at close distance such as platforms, barriers, walls, buildings can reflect noise directly towards the body of the train, high and long reflectory sided, which in turn reflects noise towards the obstacle and so on, as illustrated in figure 2. This effect is directly time related and together with directivity patterns, of great importance for the true efficiency of barriers and for noise abatment.

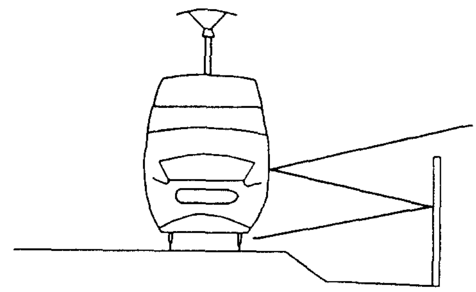

Figure 2 : Interaction between body of the TGV and a vertical screen.

3. LEVELS OF STUDY OF A PROJECT

The full 4D (3D + time) modelisation of high speed train is an accurate, but expensive method, that can be worth for final design and study of complex cases. However projects such as T.G.V./H.S.R. can have different levels of study before the final design. Each of these levels require the appropriate accuracy/method to conclude objectively.

Extensive studies : When no traject is yet fixed, the full area between two stations has to be investigated. This can only be done using a specific method that tackles the problem from the environment to the railway lines, while the other studies work from the lines to the environment. We managed such studies for example to investigate where the project between Lille and Brussels could best be placed to cause as less annoyance as possible. Different trajects were obtained from a method of poles whose aim is to reject the TGV trajects from inhabited areas according to certain rules, with a mesh of $500*500m^2$.

Intensive studies - Noise impact assessment : When the most appropriate corridors have been found in extensive studies, one must remember that the length profile of the project is obviously of great importance.

One can compare different length profiles and trajects with modelisation. When the traject is quite long, we can use *simple* 3D or "2.5D" studies that can modelise the rough profile and traject in the global environment. The level/time evolution can easily be considered from this level for computing L_{eq} values. 'Zooms' can be carried out for specific or sensitive inhabited areas. However, at this stage of study, it is not possible to take into account effects such as interactions, form of the antinoise device, directivity and so on. Then hypotheses are to be taken as : hemicylindrical waves, stationary sources, simple antinoise devices such as fine vertical absorbent barriers permitting to neglect interactions.

Once the final traject is decided, one may have a final *noise impact survey* on it. Here we can study different possibilities to protect the environment ; however it is still necessary to keep certain hypotheses to be strictly adapted to the level of noise impact surveys and nothing more : one can use moving sources and simple shape noise barriers taking their rough form into account (flat barriers, earthberms, ...) but the interactions are to be ignored here : hence only absorbent devices should once again be considered.

Intensive studies - final design : At last, when the final design of antinoise devices has to be done, we must take into account all the important parameters without forgetting any of them : directivities, moving noise sources, full implementation of time related effects as interactions, full form and acoustic characteristics of the devices.

4. BARRIERS OF DIFFERENT DESIGNS

In '93 Belgian Railways asked for a comparison study of barriers of different designs (shape and acoustic characteristics). This study was done on specific conditions as : horizontal straight line railways, infinite noise barriers and free-field propagation on an absorbent ground surface.
The comparison has been conducted on about 80 different cases of devices as earthberms and barriers of different forms, dimensions and materials. The impact of each design has been investigated for close and remote lines, as for circulations on both of them.

Examples of results are shown in figure 3 that represents the L_{eq} for 1 TGV/h at 300 km/h on vertical noise maps (from 10 to 150 m to the nearest rail and from - 15 to + 45 m with respect to this rail) with a barrier of 2.4 m high (above the rail) at 4.25 m from the rail. One can easily see the influence of the reflections between the body of the train and the barrier itself.

Mixing directivity patterns and full modelisation of the passage of a train at its normal speed allows for a clear comparison of the efficiencies of the various designs.

This comparison study was done with a linear repartition of the energy along the length of the train, what is of no problem when computing L_{eq} values. Another repartition with more power at the engines can be helpful for true level/time evolution.

5. A FINAL DESIGN STUDY

Instead of the above stated comparative study based on horizontal straight line railways in a free-field environment, final design of antinoise device should take into account the full 3D problem including topography and topology of inhabited areas.

Such different studies have been managed, mainly on the TGV North project (Paris-London-Brussels-Cologne). For example the TGV project passes through the territory of Ville of Tournai near the french/belgian border. At this place, an inhabited area is located from 25 m to 300 m (and more) away from the railway line.

The criteria of protection are L_{eq} (8-20H) $\leq$ 60 dBA and the stronger L_{eq} (20-24H) $\leq$ 55 dBA. Somewhere, for very close houses, normal absorbent vertical noise barriers needed to be 4.6 m high (above rail) or even more in order to protect the highest storeys.

A full 4D study, modelizing all the above mentionned effects and important parameters, allowed for the optimisation (about 15 different solutions) on a specific repartition of antinoise devices including earthberms and different absorbent inclined barriers, the height of which not exceeding 3.5 m above the nearest rail.

This optimization leads to a better integration of the whole project, with respect to visual, financial and safety aspects when the acoustic criteria are guaranteed.

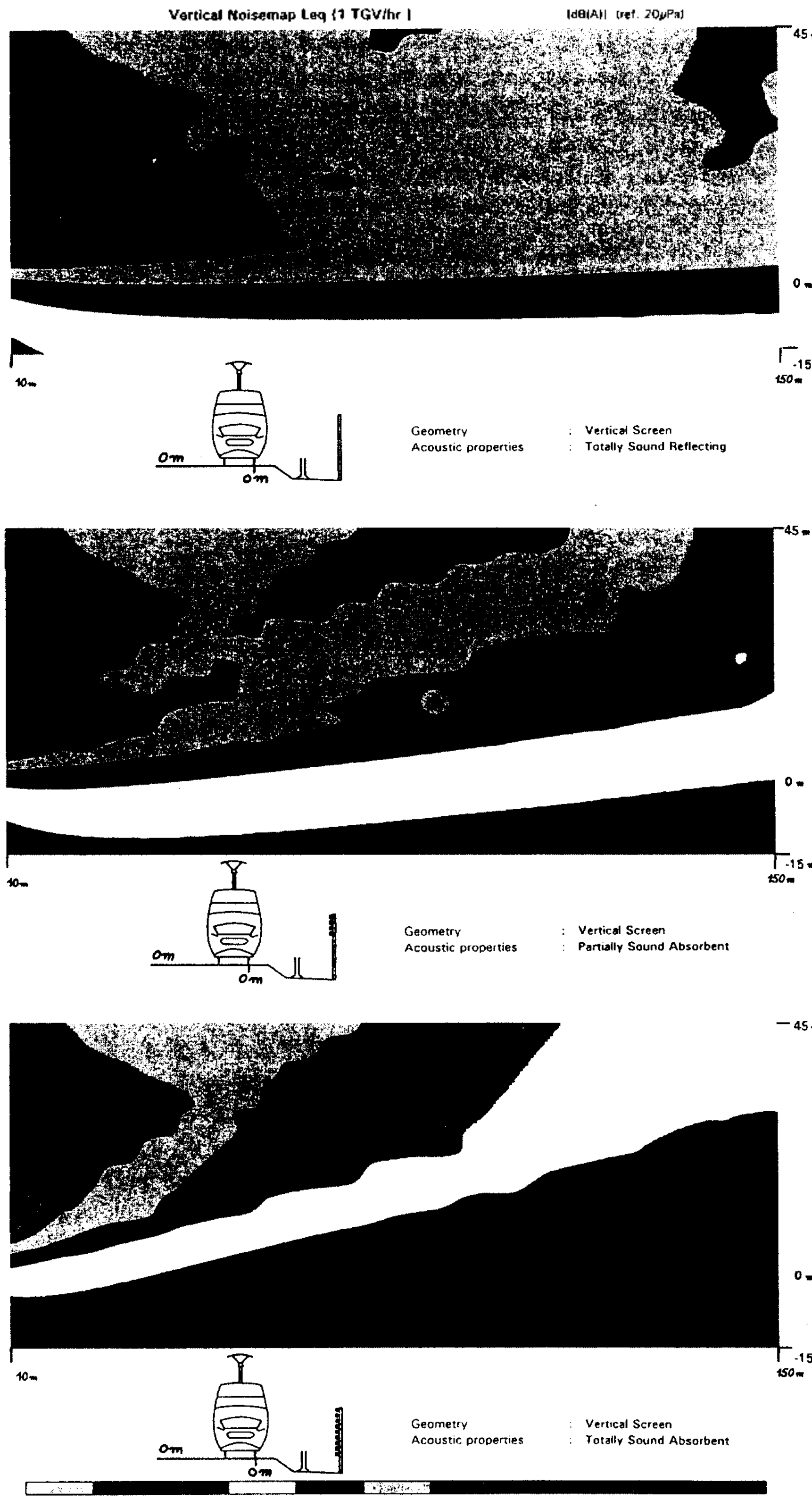

Figure 3 : Comparison of three different distributions of absorbent material on a vertical noise barrier.

6. CONCLUSIONS

Since we want to accurately design antinoise devices (in order to protect environment of high speed trains), important time related parameters, close to the physical phenomenon around moving trains, are to be taken into account.

When considering all of them, the final form and acoustic characteristics of the devices can be mastered in order to optimize the noise abatment (figure 4).

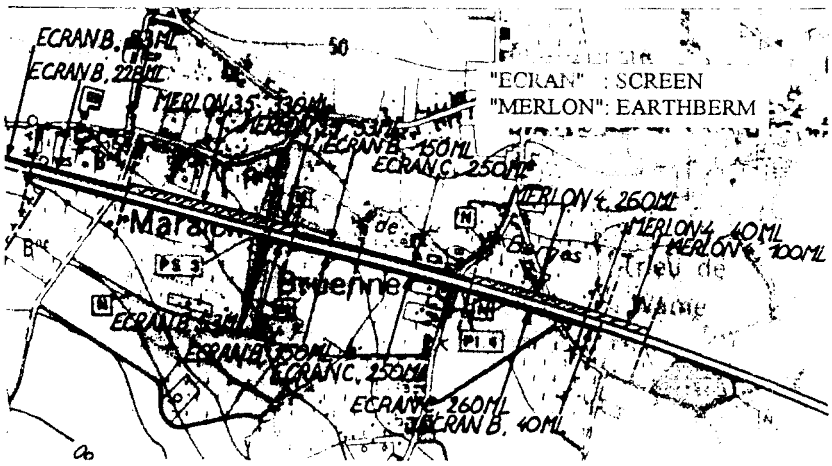

Figure 4 : Illustration of a final design of antinoise devices on site.

7. AKNOWLEDGMENTS

This work has partly been supported by Belgian Railway Company.

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