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# VIBRATION ISOLATION OF TRAINS IN A FRENCH ARTS COMPLEX

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## 1. INTRODUCTION

Rail induced vibrations are a real problem for the construction of buildings. The main reason is that the building response to the excitation is difficult to predict. That depends on many parameters such as :

- the type of train (goods train, passenger train, TGV,...)
- the characteristics of the rail
- the characteristics of the transmisson path (structure of the ground,...)
- the characteristics of the building (the response varies a lot from one structure to another).

The second problem is that, even when the vibrating energy transmitted to the structure is known, it is then very difficult to calculate the energy radiated by the different surfaces. Again it depends a lot on the type of structure.

Nowadays, models predicting the vibrating energy transmitted to the structure and the sound radiated by this excited structure have been built up, and some studies showed that only some components of the ground vibration are a source of problems (1).

When 'Le Corum' was conceived, these models were not available. The predictions had then to be worked out from previous experiences and from existing knowledge.

This paper describes 'Le Corum' project and the methodology which has been used to solve the vibration problem.

## 2. WHAT IS 'LE CORUM' ?

'Le Corum' is a large cultural and congress centre with a 2000-seat concert hall and two conference halls : 300 seats and a 800 seats, built in Montpellier (France). The building is located close to tracks where passenger trains (including TGVs but not at full speed) and heavy goods trains are passing. Fig 1 represents a layout plan where the building and the tracks are shown.

The 300-seat conference room lies about 25 meters far from the tracks, the 800-seat one 50 meters, and the 2000-seat concert hall 45 meters. This shows why it was necessary to study carefully the vibration problem.

## 3. VIBRATION LEVELS BEFORE CONSTRUCTION

Measurements were carried out in an existing building before the construction started to see whether it was necessary to protect the building (2). Fig 2 shows the old building and the measurement points. Vertical vibrations were measured at points 1 and 2, horizontal vibrations were measured at point 3.

Fig 3 shows the measurement and analysis block diagram.

Table 1 gives the 1/3 octave band velocity levels in the 0-250 Hz frequency range (ref $5\times10^{-8}$ m/s) at the first measurement point for different pass-bys and fig 4 gives the corresponding curves.

| 1/3 octave band middle frequency (Hz) | | 25 | 31.5 | 40 | 50 | 63 | 80 | 100 | 125 | 160 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/3 octave band | TGV | 42 | 44 | 43 | 43 | 40 | 47 | 48 | 44 | 33 | 23 |
| vibratory velocity | goods train | 44 | 45 | 40 | 42 | 42 | 50 | 48 | 39 | 35 | 22 |
| level at point 1 (dB) | passenger train | 50 | 51 | 49 | 48 | 45 | 44 | 38 | 36 | 42 | 33 |

Table 1 : 1/3 octave band vibratory velocity levels ref $5\times10^{-8}$ m/s at point 1

The sound radiated by the vibrating surfaces of the future building was calculated with the following formula :

$$Lp = Lv + 10 \log (4\sigma S/A)$$

where :

Lp = sound pressure level
Lv = vibratory velocity level
$\sigma$ = radiation coefficient
S = area of the surface
A = equivalent absorption area

This calculation showed that the sound pressure levels could reach NR 40 to NR 45 during a pass-by , that is around 45 to 50 dB(A). Since the client had asked for 30 dB(A) for the conference halls and 25 dB(A) for the concert hall as a ambient noise level in the future building, a vibration isolation was necessary.

## 4. THREE POSSIBLE METHODS - ONE SUITABLE METHOD

The best solution for the protection of a building from vibration is to filter as close to the source as possible. Technically, this solution is very difficult to handle and very expensive, indeed, a simple mat under the tracks is ineffective at low frequencies, that is in the interesting frequency range. For a good low frequency isolation, a very low stiffness would be needed, this would not be accepted by the SNCF because of stability problems.

Another possible method is to work on the transmission path by digging a trench between the source and the receiver. The disadvantage of that solution is that the trench has to be very deep and its efficiency decreases when the distance from the "inverse barrier" increases.

The last solution is to suspend the building on elastic bearings, that is either rubber pads, or springs.

In the case of 'Le Corum' the protection had to have an efficiency of at least 20 dB, one of the two first solutions used alone would not have been sufficient, both should have been used. For political and technical reasons the isolation of the building was then chosen.

The requirements for these elastic bearings were :

- the resonance frequency of the suspended system had to be very low since the efficiency of the isolation depends on the ratio source frequency / resonance frequency of the system

- it was necessary to be able to change the characteristics of the bearings (height in particular), to adapt them once they have been installed.

- the characteristics of each bearing had to be adapted to the weight it would carry, that means that different stiffnesses must be used at different points.

- safety warranty ; high horizontal stiffness, easy replacement, extra weight-proof, humidity-proof, age-proof, fire-proof.

The only solution satisfying all these requirements was steel spring boxes. Gerb was chosen as a manufacturer

For financial reasons, the client decided to isolate only the 2000-seat concert hall.

## 5. INFLUENCE OF THAT DECISION ON THE ARCHITECTURE

For the spring boxes to be effective, the structure of the concert hall had to be completely independent of the rest of the building. A 10 cm gap was necessary between the two independent structures. This gap had to be vibration-proof but also sound-proof and thus filled with a sound-proof joint. And for safety reasons, it had to be water-proof and fire-proof. This treble joint, of which an example is shown on fig 5, turned out to be 1600 m long.

This 10 cm gap was much more complicated than expected and was source of a lot of problems for the architects. There were many different configurations which had to be studied individually (horizontal joint, vertical joint, jonction between a vertical joint and an horizontal one, ...). This joint caused also practical problems, for example, the joint between the stage and the backstage was annoying for rolling trolleys which are used to move the equipment.

## 6. SPRING BOXES TECHNIQUE

Fig 6 shows an example of spring boxes.

A total of 280 boxes were used, with 2 different kinds of springs : one bearing 2 t, the other one bearing 6 t. The total weight supported by the boxes is equal to 23,011.83 t, that is 82.19 t per box on the average. The horizontal stiffness of the different boxes varies from 11.3 to 81.40 kN/mm and the vertical stiffness varies from 11.43 to 95.61 kN/mm. The static deflection of each box is equal to 16 mm.

The boxes are precompressed with an hydraulic jack and released once they are installed.

This technique has a lot of advantages and is not as expensive as it is often thought. One of the greatest advantage is that it is posssible to change very easily a box if necessary by compressing it and replacing it with the new one.

## 7. THE RESULTS IN ONE OF THE NON ISOLATED ROOMS (3)

After the 300-seat conference hall was completed, the client ordered measurements in this room. The reason for these measurements was that the train pass-bys could be easily heard.

The vibratory velocity levels were measured at 6 different points (one on each partition) and the sound pressure level was measured at the centre of the room. The equipment used for the measurements and analysis was the same as for the diagnosis measurements.

Fig 7 and 8 show the sound pressure levels and vibratory velocity levels spectra measured in the hall. The sound pressure levels exceed the background noise level by up to 40 dB in some of the octave bands. In dB(A), the sound pressure levels exceed the background noise level, which is equal to 21 dB(A), by 30 dB(A).

A sound pressure level of 52 dB(A) while trains are passing is higher than what was predicted. The reasons are :

- first the predicted level was calculated for concrete vibrating surfaces, the decorations were not taken into account.

- second, the radiation coefficient was taken equal to 1 for the concrete, The calculated coincidence frequency of a 30 cm concrete surface is around 50 Hz, that means the radiation coefficient of the concrete wall is greater than 1 around the 63 Hz peak of train induced vibration.

This level was then much higher than what the client had hoped.

## 8. RADIATION COEFFICIENT ESTIMATION IN THE 300-SEAT HALL

With the measurements carried out in the 300-seat hall, it was possible to check the method used to predict the sound pressure level. Knowing the vibratory velocity level of each partition, the equivalent absorption area of the room and the area of each partition, the sound pressure level was calculated with the hypothesis $\sigma = 1$. The calculated sound pressure level was then compared to the measured one, the calculated value was 4 dB lower than the measured one. This comparaison confirmed that the under-estimation of the radiated sound pressure level is due to the coincidence frequency of the concrete partitions.

## 9. THE RESULTS IN THE ISOLATED CONCERT HALL

This hall was not completed when the tests were performed. The sound pressure levels could thus not be measured. The vibratory velocity levels were measured. A comparaison of the results to the 300-seat hall results is shown on fig 9 and 10.

The vibration levels during a train pass-by are more or less the same as the background noise. The difference between the levels in the isolated and non-isolated halls lies between 15 dB around the 63 Hz peak and 50 dB at higher frequencies.

No results exist yet on the sound pressure levels as it is said before. But, although the room was not completely closed (some doors were missing), it was impossible to hear the train pass-bys during the vibration measurements.

## 10. CONCLUSION

The result was reached in the 2000-seat conference hall with a 15 dB attenuation in the 63 Hz peak.

The cost of the isolation was about 10 million francs, that is 1.5 % of the total cost of the project. The cost estimation of the isolation of the tracks combined with the trench is about 100 million francs, that is 10 times the cost of the method which has been used, however, the whole building would have been protected.

The chosen solution brought a lot of technical problems, particularly, concerning the 10 cm gap which had to be water-proof, fire-proof, vibration-proof and sound-proof. The architects spent a lot of time working out the joint path and checking that it was left clear during the construction, a single stiff connection would have ruined the gap effect. But the vibration and sound levels in the non isolated hall show that the protection was actually necessary and the good performance of the method show that the troubles were worth it.

## 11. REFERENCES

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(3) C. Leneutre, 'LE CORUM, étude de protections correctives contre les vibrations de la salle 300 places', rapport n° 254, Décembre 1989, Commins - bbm, Verrières le Buisson, France.

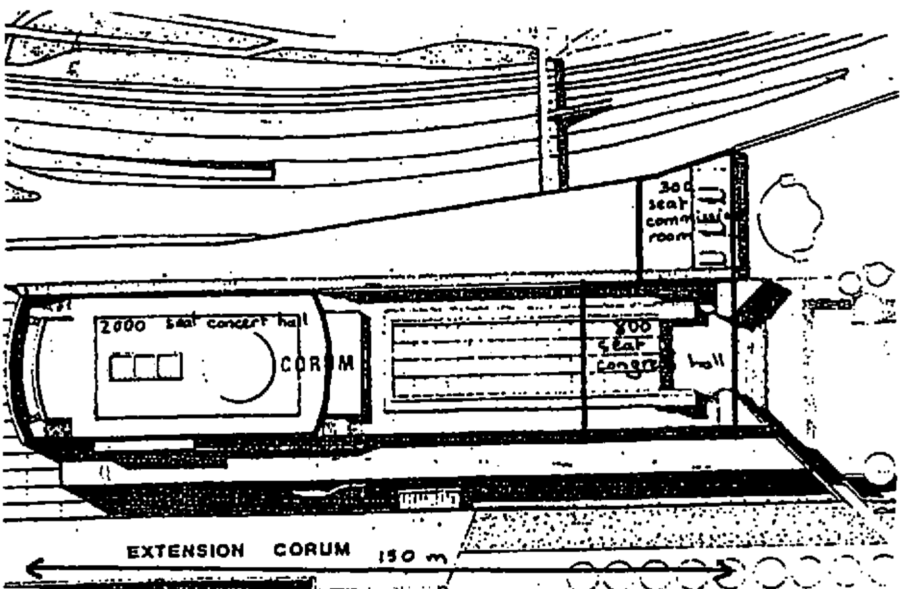


Fig 1 : Current layout plan.

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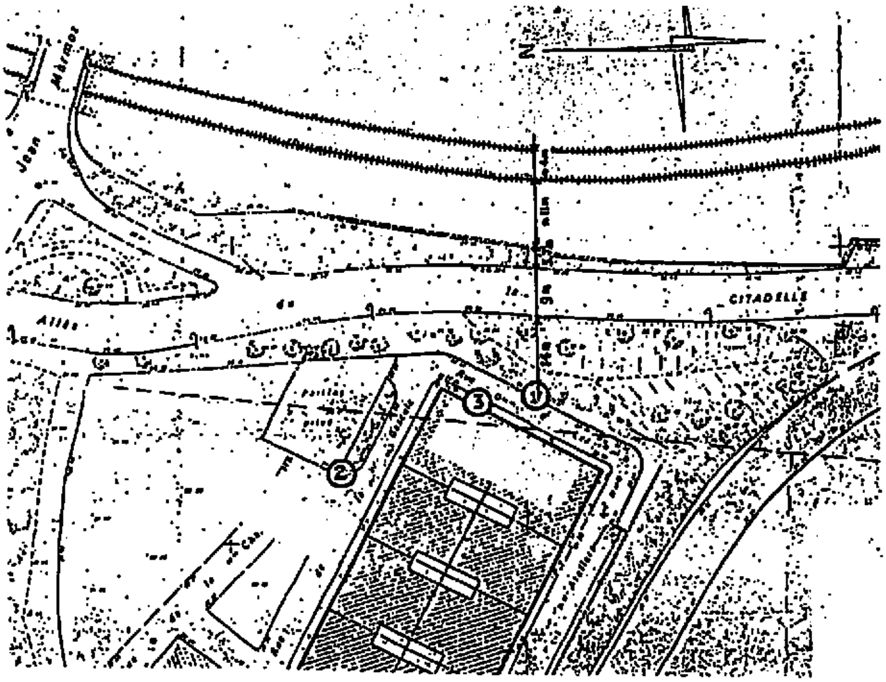

Fig 2 : Old layout plan with measurement points.

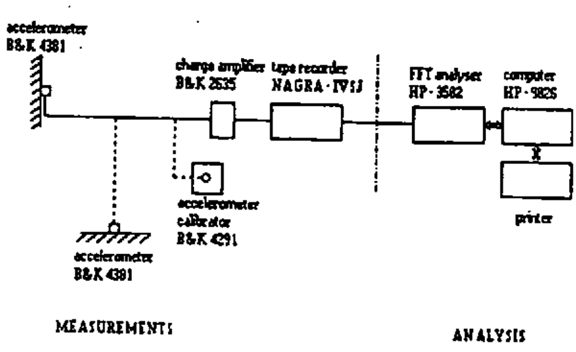


Fig 3 : Measurement and analysis block diagram.

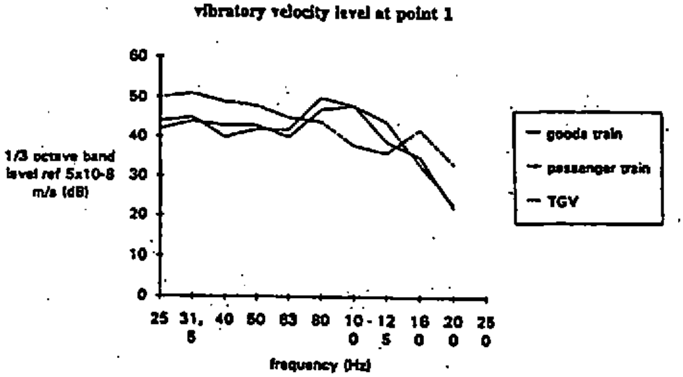


Fig 4 : Vibratory velocity levels at point 1

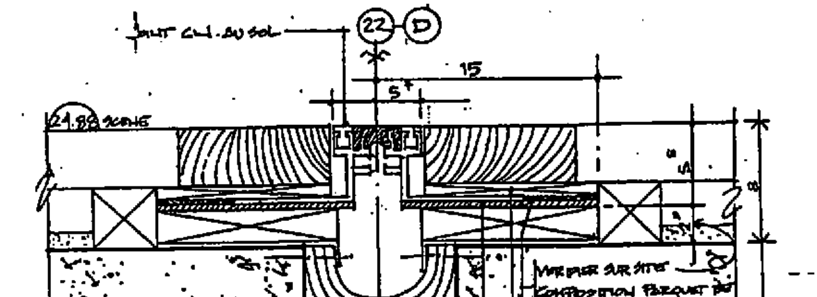


Fig 5 : Treble joint, example floor/floor

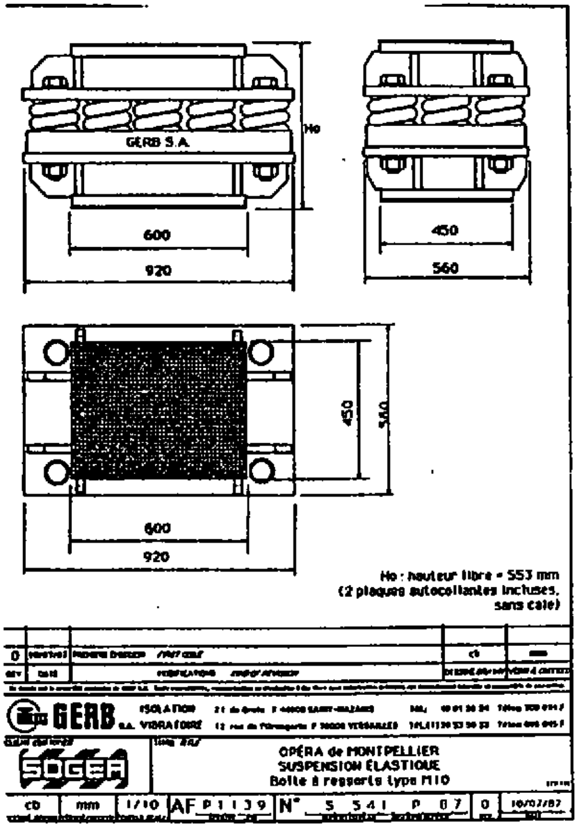


Fig 6 : Typical spring box.

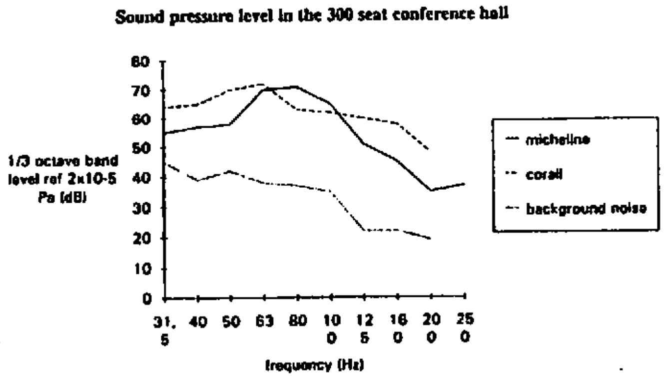


Fig 7 : Sound pressure levels in the non-isolated hall.

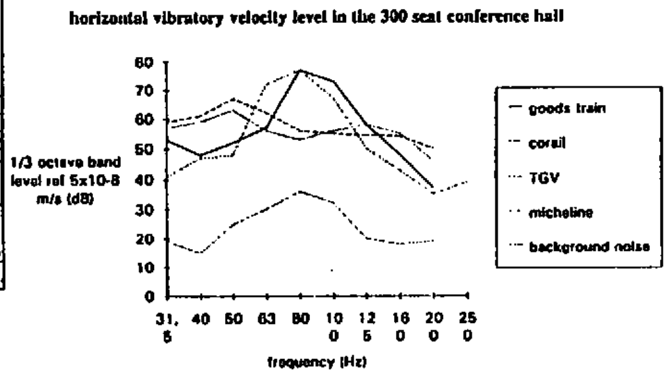


Fig 8 : Horizontal vibratory velocity levels in the non-isolated hall.

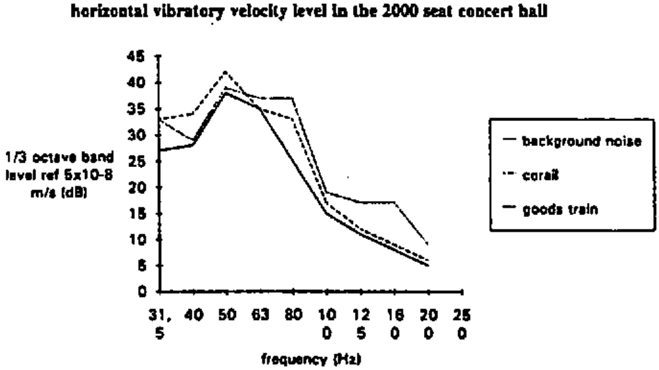


Fig 9 : Horizontal vibratory velocity levels in the isolated concert hall.

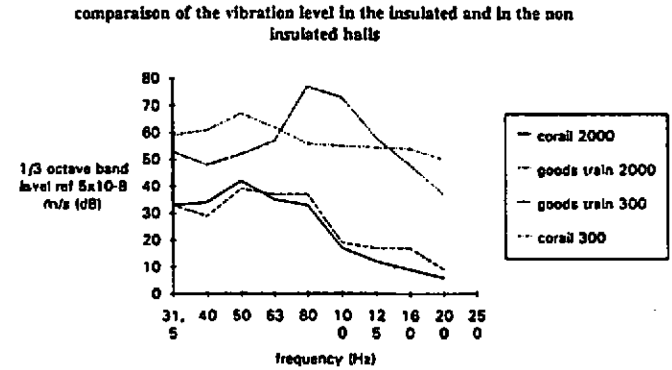


Fig 10 : Comparaison of the vibration levels in the isolated and non-isolated halls.