The Influence of a Noise Barrier on Nuisance Caused by Vibration

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Since the construction of a noise barrier beside the motorway near their home, a family suffers from nuisance caused by vibration. Prior to the building activities of the noise barrier there had never been a problem with vibration. The family is convinced that the noise barrier in some way introduces or amplifies the vibration caused by traffic using the motorway. In order to find the cause of the vibration and the relevance of the noise barrier, vibration measurements have been done. These measurements show that the traffic using the motorway is indeed the main cause of the vibration in the building. The noise barrier, however/has no influence on the vibrations. The fact that nuisance occurred in the same period as the building activities, is mainly due to the fast decline of the road-surface influenced by the building activities. The measurements also showed that the floor (especially the bedroom floor) reacted very strongly to vibration with a dominant frequency of 17 Hz. To reduce the vibration, it has been advised that the road-surface of the motorway be renewed and the possibility of modifying the floor to reduce the 17Hz resonance be considered.

1. INTRODUCTION

Since the construction of a noise barrier beside the motorway near their home, a family suffers from nuisance caused by vibration. Before the building activities of the noise barrier took place, there had never been a problem with vibration. The family is convinced that the noise barrier in some way introduces or amplifies the vibration caused by the traffic using the motorway.

Cauberg-Huygen has studied this situation in order to answer three questions:

1. What is the vibration level in the building and are the vibration limits exceeded?
2. What is the source of the vibrations?
3. What advice can be given in order to reduce the vibration level, if possible below the vibration limits?

This paper will explain the way the study was done in order to answer the questions. The paper starts by explaining the Dutch way to evaluate vibrations in relation to nuisance. If you are familiar with this information, skip sections 3 to 5 and continue reading section 6.

2. LEGISLATION

In September 2002 the Dutch Stichting Bouwresearch SBR (Foundation for Building Research) published three guidelines about the measurement and evaluation of vibrations in relation to:

- damage to buildings (Guideline A)[ref. 1];
- nuisance for people (Guideline B) [ref. 2]
- equipment (Guideline C) [ref. 3]

For the evaluation of nuisance caused by traffic, Guideline B has to be used. This Guideline is not legislation but is commonly used for matters like this and accepted by the State Council.

In the next sections the vibration parameters used and the way of evaluation are explained. If familiar with this, skip sections 4 and 5 and continue at section 6.

3. VIBRATION PARAMETERS

In Guideline B the vibration parameter that has to be evaluated is called Vmax. Before this parameter is obtained, the vibration signal has to be manipulated in 3 ways:

- the frequency range is limited form 1 to 80 Hz;
- the vibration signal is weighted;
- from the weighted signal, the effective value (rms value) is calculated.

By weighting the vibration signal, the difference in the sensitivity of humans to vibration with a different frequency, is considered. This is also done in the German standard DIN 4150 [ref.4]. Guideline B uses the same weighting.

The weighting of the vibration signal depends on the type of signal: acceleration or velocity. Both functions result in the same weighted vibration signal.

For acceleration the weighting follows the function:

$$|H_a(f)| = \frac{1}{v_0} \bullet \frac{1}{2\pi(f_0)} \bullet \frac{1}{\sqrt{1 + (f_0/f)^2}} \qquad (1)$$

If the vibration velocity is measured, the weighting is as follows:

$$|H_v(f)| = \frac{1}{v_0} \bullet \frac{1}{\sqrt{1 + (f_0/f)^2}} \qquad (2)$$

With:

- f frequency, in Hz;
- f_o 5.6 Hz;
- v_o 1 mm/s.

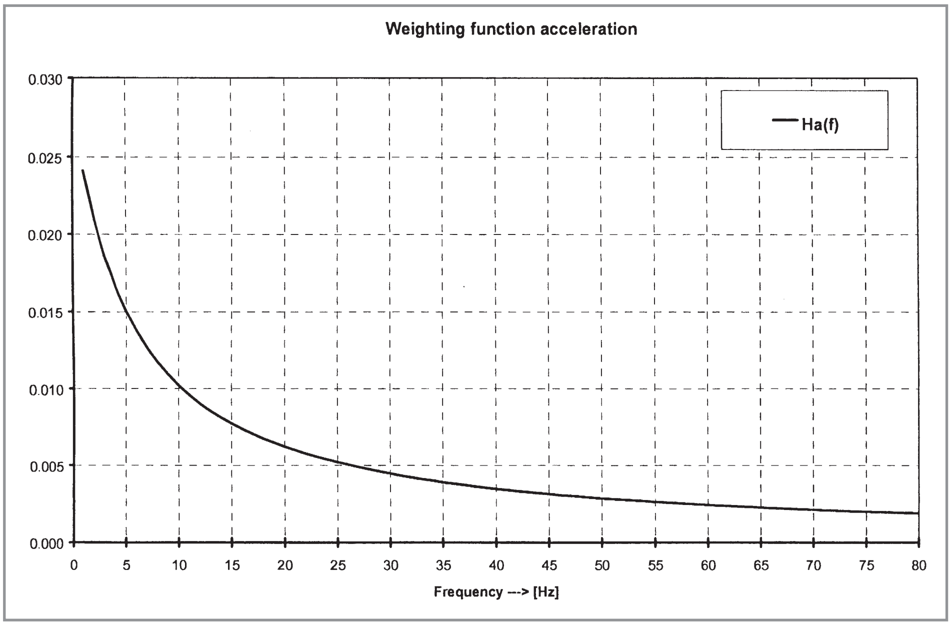

Figure 1. Weighting function for acceleration (formula [1])

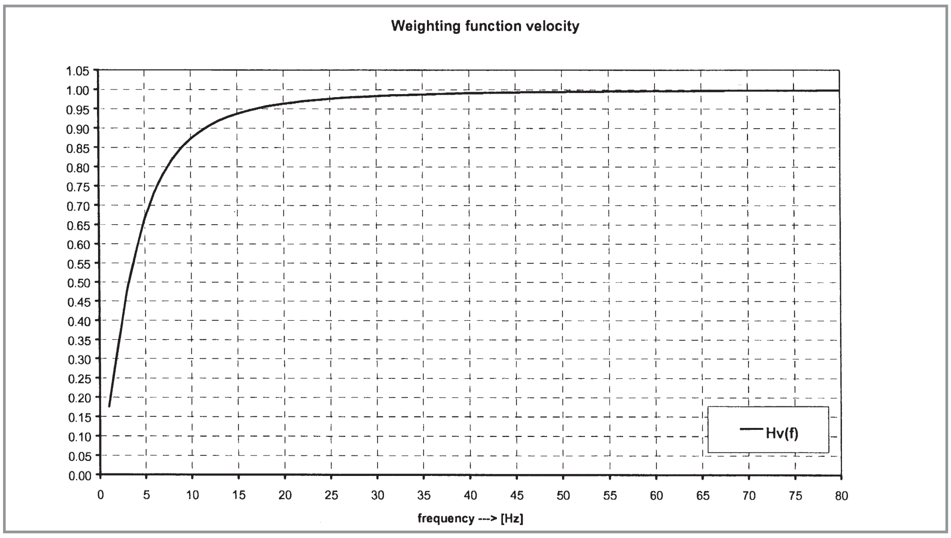

Figure 2. Weighting function for velocity (formula [2]).

By using the factor $\frac{1}{v_0}$ in the weighting functions, the weighted vibration signal is a dimensionless ratio. This is done to make clear that the vibration signal is weighted. Figures 1 and 2 present both functions as graphs.

For frequencies over 16 Hz, the weighted signal is almost equal to the unweighted velocity signal.

From the weighted signal the effective value (rms value) is calculated according to:

$$v_{eff}(t) = \sqrt{\frac{1}{\tau}\int_0^t g(\xi)v^2(t-\xi)d\xi} \qquad (3)$$

$g(\xi) = \exp[-\xi/\tau]$;
$\tau = 0.125$ s.
ξ = time in e-function

The value for τ (0.125 seconds) is the same as that used in sound level meters with the time weighting set to "FAST". For harmonic and periodical vibrations with a frequency over 10 Hz, the value of $v_{eff}(t)$ is almost constant and equal to v_{eff}. For frequencies below 10 Hz, the value of $v_{eff}(t)$ varies around the value of v_{eff}. This variation increases the lower frequencies.

During the measurement, for every interval I, of 30 seconds, the highest value of $v_{eff}(t)$ is determined. This value is called $v_{eff,max,30,i}$. Finally V_{max} can be obtained: this is the highest value of $v_{eff,mac,30,i}$. Although the determination of Vmax seems complicated, it actually is quite simple. Apart from weighting, any sound level mater with the possibility of measuring the rms value using the "Fast" integration time and a "max hold" function is suitable to do the job. Of course its frequency range for the lower frequencies should be sufficient (1-80 Hz).

4. EVALUATION OF V_{max}

The evaluation of V_{max} is done by using three limiting values called A_1, A_2 and A_3 and is done in three steps:

1. If $V_{max} < A_1$, then nuisance need not be expected.
2. If $V_{max} > A_2$, nuisance has to be expected.
3. If $A_1 < V_{max} < A_2$ a new parameter (V_{per}) has to be calculated and compared to A_3. In Vper the duration of the vibrations is considered.

Note that the first steps of the evaluation are based on the maximum value (V_{max}). One peak in the vibration signal can be enough to exceed the limits of A_1 and/or A_2.

The use of two limits (A_1 and A_2) to evaluate V_{max} has a reason. By not exceeding A_1 it is almost certain that nuisance will be prevented. By exceeding A_1 a little or not too often it is not certain that nuisance will occur. It depends on the level of the vibration and the duration. One high peak with a short duration can be acceptable. To limit the top level of the duration A_2 is used. Exceeding A_2 means that nuisance has to be expected even if the vibration lasts for a few seconds.

If the duration level (V_{max}) exceeds A_1 but does not exceed A_2, duration of the vibration level combined with the level itself is used to calculate V_{per}. To evaluate V_{per}, A_3 is used.

V_{per} is the averaged vibration level over a certain period of time. In Dutch nuisance regulations about sound and vibrations, every 24 hours is divided in 3 periods:

- Day (0.7.00 – 19.00 hours or 12 hours);
- Evening (19.00 – 23.00 hours or 4 hours);
- Night (23.00 – 07.00 hours or 8 hours).

The calculation of V_{per} consists of two parts:

- the calculation of an averaged vibration level based on the measured $v_{eff,max,30,i}$,
- the calculation of a time correction factor in which the duration of the vibration in the period of 24 hours

(day, evening or night) is considered.

The calculation of the averaged vibration level over the measurement time (vper,meet) is done according to:

$$v_{per,meet} = \sqrt{\left[\frac{1}{n} \bullet \sum_{i=1}^{n} v^2_{eff,max,30,i}\right]} \quad (4)$$

In this formula, n is the number of 30 seconds intervals in the measurement period. The value of $v_{eff,mac,30,i}$ is the highest rms value of the weighted vibration signal for every 30 seconds. If $v_{eff,\ max,30,i}$ is smaller than or equal to 0.1, the value of zero is used instead of the measured value to calculate $v_{per,meet}$. This is done in consideration of the experience that a vibration level of 0.1 or less will generally cause no nuisance. Therefore, this level is left out of the calculation. The measured interval however should be considered in the number of intervals (n) used in the calculation.

Once $v_{per,meet}$ is known, the time correction has to be obtained. This is done by:

$$\sqrt{\frac{T_b}{T_0}} \quad (5)$$

T_b represents the duration of the vibration and T_o the duration of the period (12, 4 or 8 hours).

To finalise the calculation of V_{per}, both time correction factor and the averaged vibration level have to be multiplied:

$$V_{per} = v_{per,meet} \bullet \sqrt{\frac{T_b}{T_0}} \quad (6)$$

If the measurement time has been the full 12 hours of for example the day period, the time correction will be a factor of 1. This means that $v_{per,meet}$ equals V_{per}.

If the measurement time ahs been 1 hour and gives a representative view of the vibration level but the vibration source will be active for the full period, V_{per} will also equal $v_{per,meet}$. This is due to the fact that the averaged vibration level will not change when the period of time is extended and the activities remain the same. The time correction factor will only be of influence when the vibration source is not active during the complete period.

This system of evaluation (V_{max} and V_{per}) ensures that limiting values are not used in a rigid way. For nuisance there are no definitive limits which are valid for all people. In [ref. 5] more details are given about the calculation and evaluation of V_{max} and V_{per}.

5.CONTENTS OF THE STUDY

5.1. DESCRIPTION OF THE SITUATION

The house in the study is situated about 3 metres from a main road, which is frequently used by heavy traffic. The surface of the road is asphalt. The motorway crosses the main road by a bridge. The distance between the bridge and the house is about 17 meters. The noise barrier is situated parallel to the motorway.

The noise barrier is made of concrete columns holding plates of a hard transparent synthetic material. Figure 3 shows the situation.

5.2 DETERMINATION OF THE VIBRATION LEVEL IN THE HOUSE

In consultation with the resident two rooms in their house have been selected in which nuisance occurs most. In these rooms (the bedroom on the first floor and the living room on ground level), the vibration measurements have been carried out. The measured vibration level was evaluated according to the limits given in Guideline B. Section 7 describes the results.

5.3 SOURCE OF VIBRATIONS

The vibration level in the building is possibly caused by:

1. traffic using the motorway;
2. traffic using the main road close to the building;

3. the noise barrier (since the complaints started when the barrier was built).

To determine the influence of traffic using the motorway, the traffic is observed visually and every passage of heavy traffic is communicated to the technician in the building who is performing the measurements. This way a vibration level in the building is connected to an activity on the motorway. Simultaneously vibration measurements have been carried out on the bridge close to the traffic and on the column of the bridge. The technician in the building was able to see the traffic using the main road in front of the building. This way it was possible to connect vibration level and passage over this road and distinguish the difference in vibration level caused by traffic over the motorway and the main road. During the measurements a logbook was kept of time and activity.

The influence of the noise barrier was determined by performing additional vibration measurements. The main goal of these measurements was to determine the relation between the vibration level close to the road on the bridge, on the column of the bridge and the barrier, on the foundation of the building and on the floor in the rooms. Furthermore the dominant frequencies of the barrier were measured. In section 8 the results of the search for the cause of the vibrations, are shown.

5.4 MEASURES TO REDUCE THE VIBRATION LEVEL

The last question to answer was to give advice regarding the measures that can be taken to reduce the vibration level in the building. The first step was a visual inspection of the surface of the roads. If this surface contains a lot of bumps or holes, it will introduce extra vibrations. Repairing or renewal of the surface is a possible measure to reduce the vibration level. The vibration level in the building is influence by the properties of the floor. If for example the resonance frequency of the floor is equal to the dominant frequency of the vibration level on the foundation of the building, the floor will amplify the vibration. In that case, changing the resonance frequency of the floor is a possible measure. Section 9 considers this part of the study.

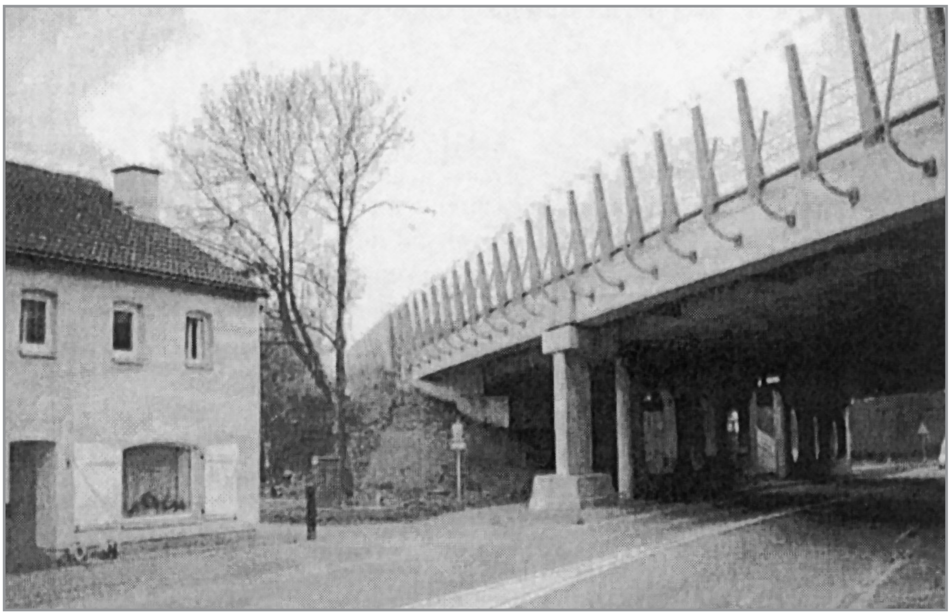

Figure 3. Situation of building, noise barrier and bridge with motorway

6. MEASURING VIBRATIONS IN THE BUILDING

6.1 GENERAL

The measurements have been carried out using the Vibra α system developed by TNO Profound. This system contains two 2D velocity pickups and a data acquisition unit. In this unit the velocity signal is stored in a way that the rms value can be calculated and a FFT analysis of the top signal can be made. The first pickup (channel 1 and 2) was placed in the building and the second pickup (channel 3 and 4) was placed outside the building for other purposes. Channel 1 and 3 measured the vertical direction and channel 2 and 4 the horizontal direction. The pickup in the building was located in the middle of the floor (living room) or close to the bedpost (bedroom).

6.2 RESULTS

Table I. presents the measured value of v_{max} for bedroom and living room and the different periods of measurement time. Note that v_{max} has no unit to make clear it is a weighted vibration level.

Table I shows that the vertical direction is dominant over the horizontal direction. This means that the evaluation of the vibration level only has to be done for the vertical direction. The vibration level in the bedroom is higher than the level in the living room. This is caused by the properties of both floors. The floor in the living is made of concrete with two layers of piles. A rather heavy and stiff floor compared to the floor of the bedroom, which is made of wood covered with a (thermal) insulation layer and another layer of wood. The results match the perception of the inhabitants. They claim that the vibrations in the bedroom are most strongly felt.

6.3 EVALUATION OF THE MEASURED VIBRATION LEVEL

The first question was to measure the vibration level in the building and evaluate this level using the limits in Guideline B. The vibration level V_{max} is 5.77 in the bedroom and 0.16 in the living room.

The limits depend on the use of a building, the type of vibration source and the period in which the vibration occurs. In this situation, the building is used for living, the vibration source is characterised as repeatedly occurring and the vibrations occur in all periods (day, evening and night) since traffic is possible in all these periods. For repeatedly occurring vibrations there are three situations:

1. <u>new</u>: when for example a new vibration source is introduced like a speedhump or a new road or a new building is build;
2. <u>existing</u>: when both building and vibration source already exist;
3. <u>changed</u>: when a certain change is made to a vibration source like a new surface of the road or an increase in the intensity of the traffic.

Table I. Results of vibration measurements in the building

Location	Time	v_{max} [-]		
			vertical	horizontal
	bedroom	11:02-11:34	1.39	0.09
		11:49-12:18	1.84	0.12
		14:12-14:31	5.77	0.30
	living room	12:39-13:07	0.16	0.09

Table II. Limits used for V_{max}

Situation	Day			Evening			Night		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
Living"existing"	0.2	0.8	0.1	0.2	0.8	0.1	0.2	0.4	0.1
Living "new"	0.1	0.4	0.05	0.1	0.4	0.05	0.1	0.2	0.05

In the situation "new" the vibration limits are lower compared to the situation "existing" because in the situation "new" it is possible to use the design of vibration source or building to reduce the vibration level. For the situation "existing" higher limits are allowed because people are more or less accustomed to a certain level of vibrations and nuisance is less likely to occur.

The situation "existing" seems appropriate in this study because both roads and building already existed when the complaints started. Nevertheless, the complaints started when the noise barrier was built which implies a change of the situation. Therefore the situation is evaluated according to the situation "changed".

For this situation, the "stand-still" principle is used for the vibration limits. This means that the change should not make it worse. Unfortunately the vibration level before the building of the barrier started, is not known. In that case the vibration level should not be over the limits for the situation "existing" and doesn't need to be under the limits for the situation "new". Table II presents the limits used.

For the bedroom A_2 is clearly exceeded (5.77 over 0.8 and 0.4). This means nuisance is expected.

For the living room, A_1 is exceeded but A_2 is not. This means that V_{per} has to be calculated in order to compare to A_3. For the most critical period (night) and situation ("new") 94 passages with a vibration level of 0.16 are allowed before A_3 is exceeded.

Based on the counting of heavy traffic, this is not likely to happen, so for the living room nuisance is not likely to occur.

6.4 SUMMARY

The answers to the first question in this study are:

- the vibration level V_{max} in the building is 5.77 (bedroom);
- the limits in Guideline B are exceeded and
- nuisance is likely to occur.

It is time to find the source of the vibrations. Section 8 describes the search.

7. LOOKING FOR THE SOURCE

7.1 GENERAL

The vibration level in the building is possibly caused by:

1. traffic using the motorway;
2. traffic using the main road close to the building;
3. the noise barrier (since the complaints started when the barrier was built).

In the following paragraphs these possible causes are explained.

7.2 TRAFFIC USING THE MOTORWAY

During the measurements, the traffic on the motorway was observed. The passage of heavy traffic was communicated to the technician in the building. Based on these observations, it is concluded that traffic on the motorway causes the highest vibration levels. Especially when two passing lorries were entering the bridge and passing the noise barrier, the pressure wave close to the motorway was very strongly felt by the observer. The vibration measurements simultaneously carried cut close to the motorway and in the bedroom confirm this conclusion. Figure 4 presents both vibration levels.

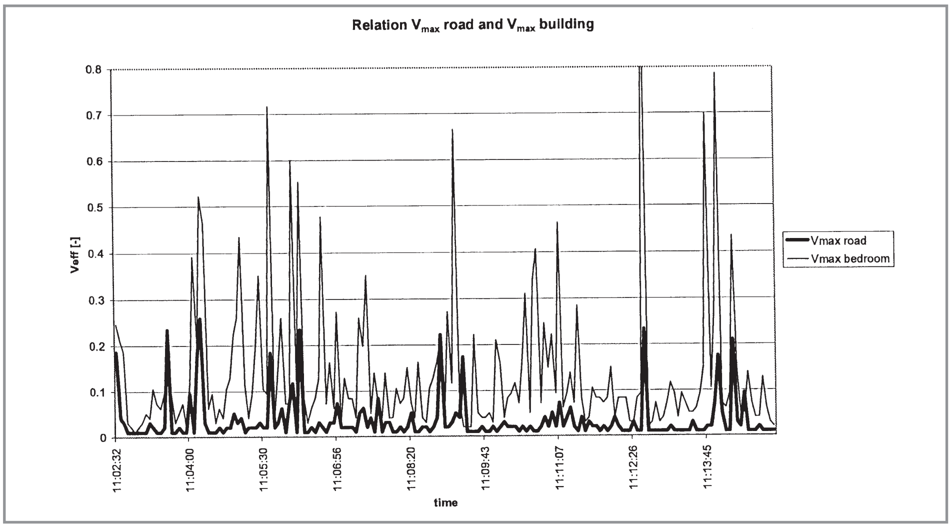

Figure 4. vibration level on bridge and in bedroom

It is clearly seen that the vibration level in the bedroom exceeds the vibration level close to the road. It is also seen that for most of the highest peaks, the vibration level simultaneously rises on both measuring positions.

Since the motorway is a dual carriageway, traffic entering the bridge in the opposite direction causes vibration as well. This traffic has not been separately monitored but will cause some peaks in the vibration level in the building without causing a peak close to the road.

7.3 TRAFFIC USING THE MAIN ROAD

The technician in the building monitored the traffic using the main road. The vibration level caused by this traffic varies between 0.12 and 0.58 in the bedroom. The vibration level caused by the traffic using the motorway varies between 0.62 and 5.77 with a lot of passages with a vibration level over 1. Based on these observations the traffic using the motorway is the main cause for the nuisance by vibrations.

7.4 THE INFLUENCE OF THE NOISE BARRIER

The inhabitants stated that once the drilling activities for the foundation of the barrier had started, vibrations were frequently felt especially in the night when no building activities were carried out. The influence of the barrier is studied by:

1. measuring the vibration level on the column of the existing bridge and the column of the noise barrier in order to compare both vibration levels;
2. measuring the dominant frequency of the barrier when heavy traffic is passing the barrier to find out if this frequency can be found in the building.

7.5 VIBRATION LEVEL ON THE COLUMN OF THE BARRIER

Figure 5 presents the vertical (kanaal 3) and horizontal (kanaal 4) vibration level on the column of the barrier.

Figure 5 shows that the vibration level varies between 0.03 and 0.085. The horizontal direction is slightly dominant over the vertical direction. The average vibration level is 0.07 (horizontal direction).

7.6 VIBRATION LEVEL ON THE COLUMN OF THE BRIDGE

Figure 6 presents the vertical (kanaal 3) and horizontal (kanaal 4) vibration level on the column of the bridge. Although not simultaneously measured with the measurements on the column of the barrier, it is possible to compare both positions based on the average vibration level.

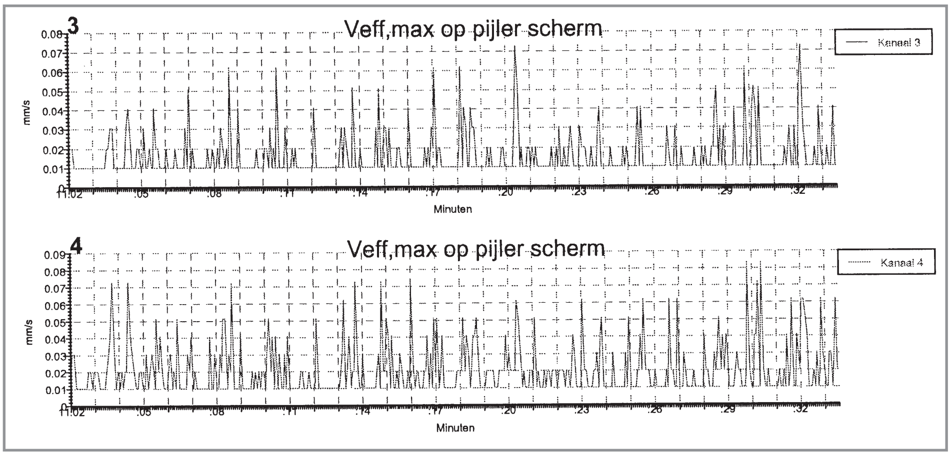

Figure 5. Vibration level of column barrier (Dutch title: $v_{eff,max}$ op pijler scherm).

Figure 6 shows that the vibration level varies between 0.05 and 0.20. Many passages of heavy traffic cause vibration levels over 0.1. The vertical direction is dominant over the horizontal direction. The average vibration level is 0.133. This is almost twice the value of the average vibration level on the column of the barrier (0.07). This mans that the column of the barrier does not cause as much vibrator as the column of the bridge. But the column of the barrier is located 5 meters/closer to the building than the column of the bridge. Therefore a calculation has been made to determine the contribution of both vibration sources on the foundation of the building to find out if the vibration level caused by the barrier is relevant for the overall level.

7.7 CALCULATION OF THE VIBRATION LEVEL

For the calculation, the formula of Barkan is used:

$$V_R = V_{Ro} \cdot \left[\frac{R_o}{R}\right]^n e^{-\alpha(R - R_o)} \qquad (7)$$

V_R vibration level [m/s] on a distance R

V_{ro} vibration level [m/s] on a distance R_o

R distance between a point and the vibration source [m]

R_o distance between reference point* and vibration source [m]

α property of the soil [1/m]

n factor depending n type of wave
n = 1 to 2 for P- and S-waves
n = 0,5 for R-waves

*The reference point should be located at a certain distance from the vibration source.

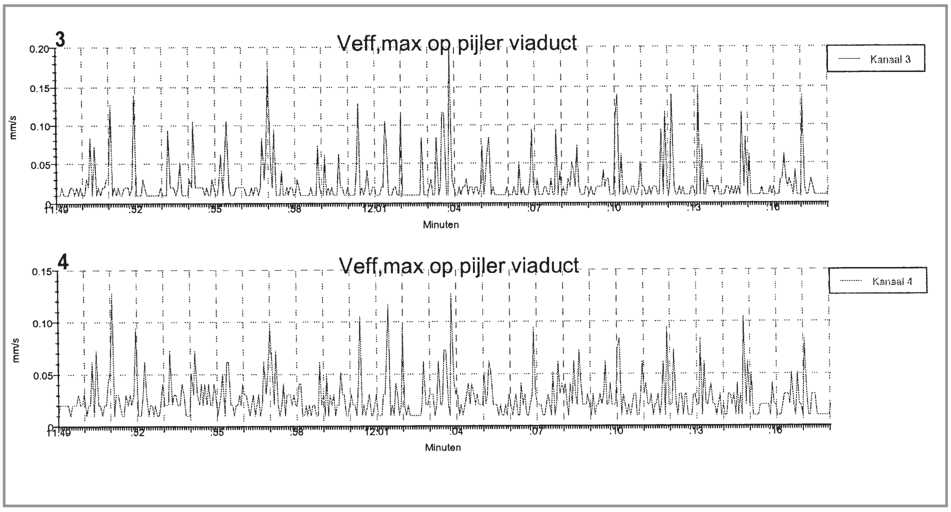

Figure 6. Vibration level of column bridge (Dutch title: veff,max op pijler viaduct)

In this situation the parameters presented in table III are use for the calculation.

Table III. Calculation parameters

Parameter	Source 1 (bridge)	Source 2 (barrier)
VRO	0,21 (maximum Value)	0.082 (maximum Value)
R0	1 m	I m
R	17,5 m	12,5 m
a	0,03	0,03
n	0,5	0,5

The calculated vibration level on the foundation of the building is:
0.0306 for source 1 (bridge)
0.0171 for source 2 (barrier)

The overall level is **0.0351**. The contribution of the vibration source "barrier" is not very relevant according to the overall level.

7.8 VIBRATION OF THE BARRIER

Vibration measurements have been carried out on two of the transparent plats of the barrier (number 3 and number 11). The plates are light compared to the concrete parts of the barrier and therefore more likely to vibrate when heavy traffic is passing. Using two B&K acceleration pickups (type 4396) and a FFT analyser (brand D1), the dominant frequency of the barrier is measured when traffic passes. The pickups were placed in the middle of the barrier plate.

Figure 7 shows the measurement result of the averaged vibration level over four passages.

The dominant frequency of the barrier plate is 13 Hz. Inside the building, a frequency analysis of the vibrations of the bedroom floor has been done to see if this frequency is found.

7.9 DOMINANT FREQUENCY OF THE BEDROOM FLOOR

Figure 8 shows the result of a frequency analysis (power spectrum of the vibration velocity (in Dutch: snelheid)) of the maximum value (5.77). Channel 1 (kanaal 1) and 2 (kanaal 2) display the vertical and horizontal direction of the bedroom floor. Channel 3 and 4 represent the same directions but measured on the foundation of the building.

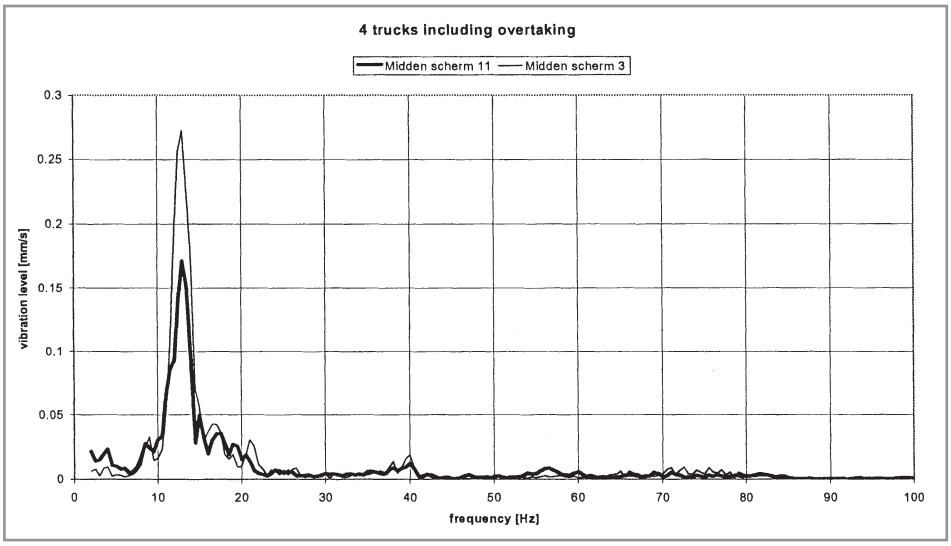

Figure 7. Averaged vibration level of transparent part of barrier

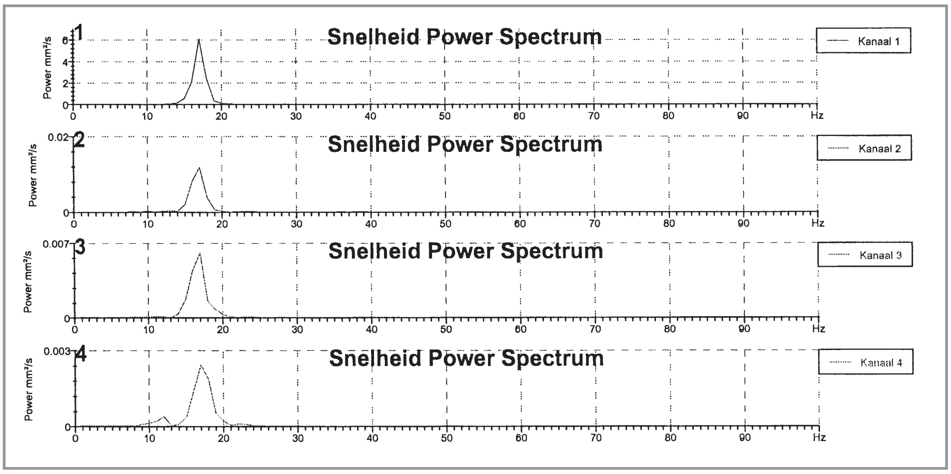

Figure 8. Power spectrum of vibration velocity bedroom floor and foundation building

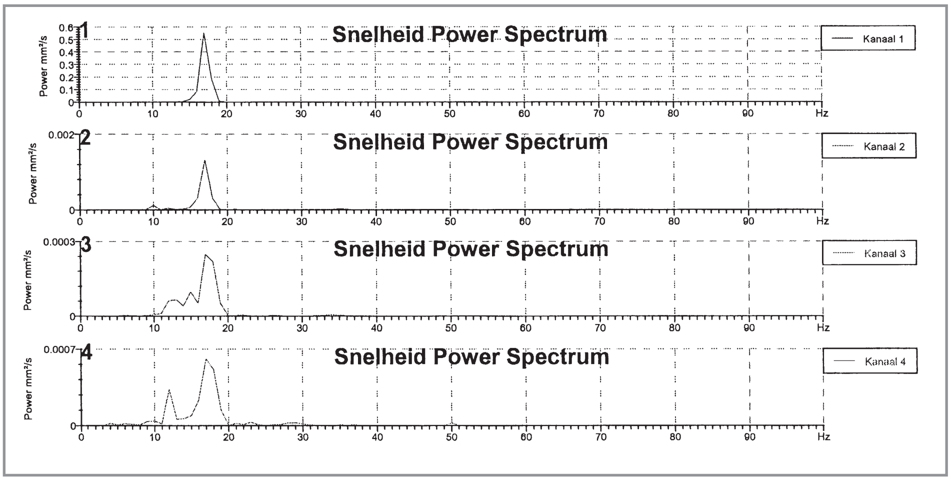

Figure 9. Power spectrum vibration velocity bedroom floor and column barrier

Neither the bedroom floor, nor the foundation respond with a 13 Hz peak. The dominant frequency is 17 Hz. So another top value (V_{max} is 1.39) of the vibration level in the bedroom is analyses. Figure 9 shows the result. Channel 1 and 2 were measured on the bedroom floor, channel 3 and 4 on the column of the barrier.

This figure shows that only on the column of the barrier is 13 Hz found. The dominant frequency of 17 Hz is also found at both measuring positions.

7.10 SUMMARY LOOKING FOR THE SOURCE

The vibration measurements and calculations show that:

- traffic using the motorway is causing the highest vibration levels in the building;
- vibrations caused by the barrier are not relevant to the total level of vibrations measured on the foundation of the building;
- the dominant frequency of the barrier (13 Hz) is not present on the bedroom floor.

8. HOW TO REDUCE THE VIBRATION LEVEL

8..1 GENERAL

In order to give advice about the measures that can be taken to reduce the vibration, three aspects have been studied:

1. the status of the road-surface of the motorway;
2. the transfer of vibrations through the ground;
3. the reaction of the floor to vibration.

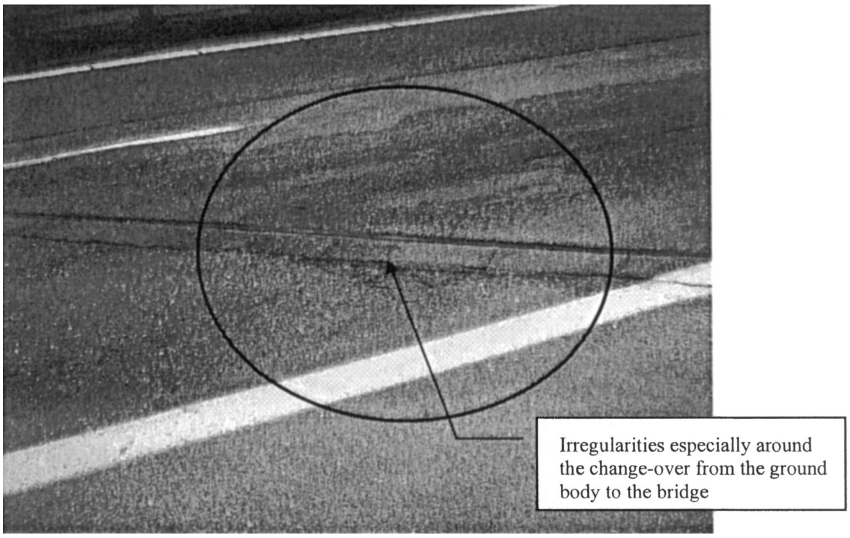

Figure 10. Irregularities road-surface motorway.

8.2 STATUS OF THE ROAD-SURFACE, MOTORWAY

The road-surface of the motorway shows lots of irregularities especially around the change-over from the ground body to the bridge. Figure 10 shows an example.

These irregularities are responsible for more vibration compared to a smooth road-surface. Changing ore renewing the road-surface of the motorway will reduce the vibration level.

8.3 TRANSFER OF THE VIBRATIONS THROUGH THE GROUND

The inhabitants have mentioned that the nuisance started the moment when the building of the barrier started. The idea is that the foundation of the barrier is in some way connected to the foundation of the building thus transferring the vibration more effectively. A connection between these foundations should only affect the vibration level in the horizontal direction. If the vertical direction of the connection will simply follow the movement of the ground without influencing it because the mass of the connection is low compared to the mass of the moving ground layers and because the stiffness is not high enough to lift the building vertically. The results of the measurements show that the horizontal direction is not relevant for the vibration level in the building. This means that a connection between the foundations (if existing) is not affecting the vibration level in the building.

Furthermore the contractor has stated that all parts of old foundations or sewer pipe have been removed to avoid any connection between the foundation of the barrier and the foundation of the buildings around it.

8.4 REACTION OF THE FLOOR TO VIBRATIONS

By exciting the bedroom floor using a hammer with a vibration transducer and measuring the response of the floor to this blow, the dominant frequency of the floor is measured. Figure 11 shows the result.

The coherence of this measurement was not as good as it should have been. Nevertheless for the dominant frequencies of 17, 34 and 44 Hz, the coherence is 0.96 or higher which makes the measurement useful for these frequencies. The result of 17 Hz is no surprise regarding the results of the vibration measurements. Since this frequency is also dominantly present in the foundation of the building and the foundation of the barrier, it is clear the bedroom floor amplifies the vibration level at this frequency. Changing the reaction of the floor to this frequency will reduce the vibration level.

9. CONCLUSION AND ADVICE

The conclusions of this study are:

1. The vibration level in the building (especially the bedroom) considerably exceeds the limits thus explaining the complaints of the inhabitants;
2. The main cause is traffic using the motorway;
3. The newly built noise barrier has no influence on the vibration level in the building;
4. The fact that nuisance occurred in the same period the barrier was built, is due to a rapid decline of the road-surface mainly caused by the building activities;
5. The road-surface of the motorway shows a lot of irregularities which cause additional vibration;
6. The bedroom floor reacts strongly to a frequency of 17 Hz which is dominantly present in the vibration on the foundation of the building.

In order to reduce vibration, the following advice is given:

1. Renew the road-surface of the motorway thus creating a smooth surface;
2. Consider re-building the bedroom floor to remove the resonance at 17Hz.

Note that once the traffic using the motorway is no longer a dominant vibration source, the traffic using the main road just in front of the building will still cause vibrations that can be felt in the building. These vibrations also have to be reduced in order to completely meet the limits from Guideline B. Changing the floor is a possible way to achieve this.

REFERENCES

1. Deel A *"schade aan gebouwen", meet en beoordelingsrichtlijn, (Part A "damage to buildings", guideline for measurements and evaluation of vibrations)*, Stichting Bouwresearch (Foundation for Building Research), September 2002 (in Dutch)

2. Deel B *"Hinder voor personen in gebouwen", meet- en beoordelingsrichtlijn over trillingen, (Part B "nuisance for people in buildings"*

Figure 11. dominant frequency bedroom floor after excitations with hammer.

SNOWMOBILES

Noise emissions at three key spots in Yellowstone National Park were "subsequently lower" last winter, but still routinely exceeded thresholds set by the National Park Service, a new study shows. Despite lower snowmobile numbers and requirements that the machines be cleaner and quieter, researchers in the park said noise continued to be an issue at three monitoring sites: near Old Faithful, at the West Yellowstone entrance and at Madison Junction. Researchers tallied about 1500 instances at the three monitoring sites in which noise levels exceeded the Park Service's threshold of 70 decibels. The majority of the cases involved snowmobiles, although snowcoaches also exceeded limits but not as frequently. Seventy-seven instances were attributed to a snow grooming machine. The monitoring report is the latest in a series of reports that have been released recently looking at the effects of snowmobile and snowcoach travel in the park last year. Noise and air pollution and their effects on wildlife and habitat have been key issues in the debate over motorised use in the park. The Park Service has said that preserving natural quiet is an important part of its mission.

guideline for measurements and evaluation of vibrations), Stichting Bouwresearch (Foundation for Building Research), September 2002 (in Dutch).

3. Deel C "*Storing aan apparatuur*", *meet en beoordelingsrichtlijn, (Part C "Description of equipment", guideline for measurements and evaluation of vibrations)*, Stichting Bouwresearch), September 2002 (in Dutch).

4. German Standard DIN 4150 part 2 (in German).

5. C. Ostendorf, "Nine Years of Dutch Experience in the Evaluation of Vibrations in Relation to Nuisance", *Journal of Low Frequency Noise, Vibration and Active Control*, volume 21 number 4, 2002.

6. Report 2003. 2577 – 1 dated 20th April 2004 by Cauberg-Huygen Raadgevende Ingenieurs (in Dutch).

SHREWSBURY ROADWORKS

Sleep-deprived Shrewsbury residents hit out at council bosses after late-night workmen kept them awake until the early hours. People living in Longden Coleham said the roadworks did not stop until 2 a.m. and the noise was so loud they were forced to keep their windows closed on one of the hottest nights of the year and park their cars in the next street to avoid dust. And despite receiving letters from the county council informing them of the work, many residents said they had not been told heavy trucks and machinery would be in use to late. Resurfacing work and other improvements began in July and the project is scheduled for completion in September, just in time for the new school term. But Dan Sims, engineering assistant for the county council, said overnight work had always been programmed as part of the scheme and thorough consultation had been carried out. He said: "Letters were sent out to residents and businesses and signs were put up on the road saying that it would be closed overnight for resurfacing work."

EARLY MORNING MOTORBIKE

A Lake Township man is fighting a disorderly conduct charge that stems form his loud motorcycle. A neighbour complained about the noise that Michael Brandt makes as he drives away to work in the early morning hours. He pleaded innocent and his attorney hopes to have the case resolved soon. Another court hearing is scheduled. Canton City Prosecutor Frank Forchione said he tried to mediate the problem, but Brandt refused to meet with him, an action that resulted in the disorderly conduct charge. Neighbors in his allotment are upset by the loud motorcycle that roars through their neighbourhood between 2 and 3 a.m., court records say. A complaint was filed on 22 August by Jocelyn Harhay, one of Brandt's neighbors. Harhay would not comment on the situation and referred questions to her attorney. Brandt could not be reached for comment. "We did everything we could to try to mediate this problem," Forchione said. The prosecutor said he sent Brandt a letter asking for a meeting, and that Brandt didn't respond. He said he then asked Brandt to bring the motorcycle downtown, and Brandt refused. "I agreed to go out there with his lawyer and listen to it myself," Forchione said. But before he could, he got a phone call telling him that the meeting was off and that Brandt would take another route out of the neighbourhood. Forchione said the new route lasted only a couple of weeks before the motorcycle was again upsetting the neighbours. "We gave him three chances, and he did not cooperate," he said. "I took the case to the judge. Judge (John A.) Poulos found probable cause for disorderly conduct. If (Brandt) had cooperated with the prosecutor's office, we would not be (in this situation) today. We really did try to resolve this thing," Jeremy Foltz, Brandt's attorney, said he had not heard the motorcycle, but he called the disorderly conduct allegation "a catch-all charge."