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## In-situ evaluation of the acoustic efficiency of a green wall in urban area

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### ABSTRACT

In urban areas, the last few years have seen an increase of developments of green walls, roofs and façades, which help to give back space to plants in towns. The primary purpose of this type of device is very often an aesthetic issue but the question of using them to reduce noise may arise. In this context, and as part of a French research project involving other scientific topics, an acoustic measurement campaign was conducted by Cerema around a green wall site (rue de la Préfecture in Cergy, near Paris). The evaluation involved the characterization of the street sound environment, before and after setting up the wall:

- by directly measuring the road traffic noise.
- by collecting acoustic signals generated by an omnidirectional speaker.

It is shown that the infrastructure tends to reduce noise levels in the street, by observing:

- moderate noise reduction (between 0 and 6 dB gain) at medium frequency (400-2500 Hz) that can be put down to acoustic absorption due to the planting substrate.
- maximum efficiency at high frequency (between 0 and 10 dB of gain above 3150 Hz) where a scattering phenomenon caused by the foliage also comes into play.

Keywords: Green wall, Scattering, Absorption materials  
35.4.1.

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## 1. INTRODUCTION

In urban areas, the last few years have seen an increase of developments of the green wall, roof and façade type. Many projects already include these systems that help to give back space to plants in towns. The primary purpose of this type of device is very often an aesthetic issue but the question of using them to reduce noise may arise.

In this context, an acoustical measurement campaign around a site hosting a green wall was carried out to highlight its potential effectiveness in reducing noise pollution in its environment. Here we present the main results of this evaluation.

## 2. ACOUSTIC IMPACT OF GREEN WALLS: CURRENT KNOWLEDGE

At the scale of a street or a district, a reduction in noise levels in the vicinity of such developments is primarily related to a sound absorption gain generated by use of the device (especially the planting substrate). The direct effects of this absorption have been demonstrated by characterizing certain commercially available products in laboratory (1,2). Previous studies (3,4) have also quantified the acoustic impact of green roofs from digital models validated by measurements but for a limited number of configurations. Moreover, these studies did not attempt to characterize the impact of green façades.

A recent study (5), based on a systemic approach to the consideration of plants in towns, was used to numerically evaluate the impact of green façades on the scale of a street canyon based on impedance characterization measurements of some existing devices.

At this stage, it nevertheless appears that:

- few in-situ experimental studies have been carried out on the subject, resulting in a lack of field data for the scientific community ;
- the durability of the acoustic characteristics generated by these devices has not been assessed (time representativeness) ;
- the spatial representativeness of the growing media, related to the inhomogeneity of the plant systems, remains to be studied.

## 3. TYPOLOGY OF COMMERCIAL GREEN WALLS AVAILABLE ON THE MARKET

Three types of method have been mainly developed by manufacturers to develop green walls:

- first method: using a thin substrate for growing plants (usually rot-proof felt). It is used to cover a wall or existing façade, but can also be placed on an independent structure and thereby be self-supporting.
- second method: using honeycomb plant supports that can be of different types (ceramic, concrete or expanded polypropylene). These honeycomb plant supports are generally tilted, to allow plants that are ill-suited for growing in an upright position to be planted.
- third method: using planting substrates inserted in metal modules or cages (Figure 1). The components of the substrate contained in the growing medium are mostly of mineral (rock wool or clay), vegetable (Chilean sphagnum moss or coconut fibre) or animal origin (micro-organisms or bacterial yeast).

As an initial approach, the third method is the one with the most features likely to have an acoustic effect. These devices consist of usually fairly substantial substrate thicknesses (15 to 40 cm) that may be of interest in terms of sound absorption. These substrates are held in place using light envelopes (rot-proof geotextile) and can be self-supporting (sphagnum moss) and therefore offer few or no obstacles to their sound absorption potential.

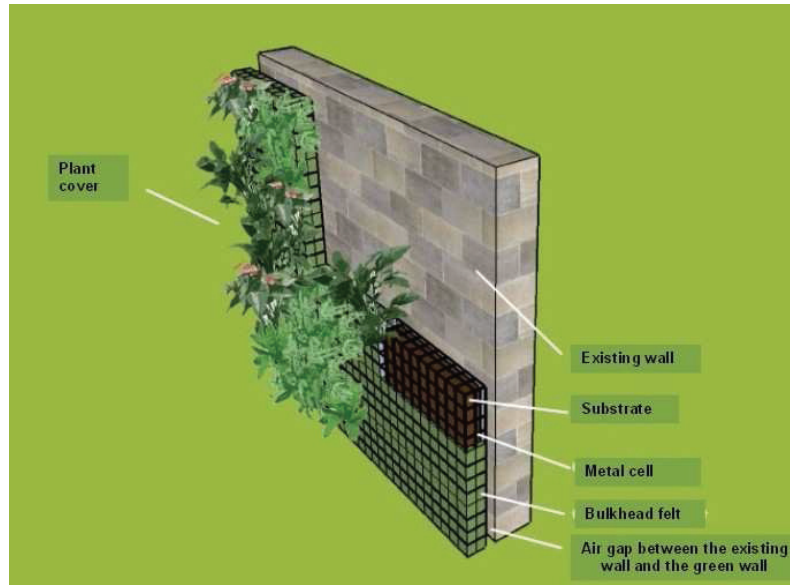


Figure 1 - Green wall using planting substrates in metal modules

The evaluation presented in this document was carried out on a wall of this type.

## 4. PRESENTATION OF THE STUDY SITE AND THE PLANT DEVELOPMENT

### 4.1 Study site

The test site chosen for this evaluation is located in Cergy, in the Val d'Oise department, near Paris (France). The Conurbation Community expressed the wish to cover a retaining wall along a busy street in the town centre with a natural covering (rue de la Préfecture).

Rue de la Préfecture is a two-way street with two lanes. It is used by about 6,200 vehicles per day, travelling at an average speed of 30 km/h. On the façade opposite the retaining wall, there is a two-storey public building (the public library, Figure 2).

From a technical perspective, this road was of interest because:

- of its rather closed-in configuration, almost like a U-shaped street and therefore likely to maximize the effects after creating the green wall. Furthermore, the lack of parking areas in the relevant section of road would help prevent heterogeneity in terms of the level of obstruction in the street between the two planned measurement periods (measurement protocol performed in similar conditions before and after setting up the green wall).

- of the absence of interfering sound sources: besides road traffic noise, no other urban source that might pollute measurements made outdoors was identified beforehand



Figure 2 - overview of the study site

## 4.2 The green wall

The greened area is approximately 150 m<sup>2</sup> (a rectangle 26.8m by 5,64m).

The green wall is made up of (Figure 3):

- a structure consisting of galvanized steel cells having a front face and four sides of 100 X 100 mm mesh made with Ø6mm wire connected by corner pieces of section 25 X 25 X 3 mm. The "typical" cell is 1940 X 1920 X 340 mm ;
- a filling for the cells with a polypropylene rot-proof fabric surrounding the planting substrate (a mixture of organic and plant materials, substrate thickness 200 mm) ;
- plants selected on the basis of the climatic conditions of the place where the wall is installed (the Cergy wall has 39 different species and 5,945 plants) ;
- an irrigation system consisting of micro-drip pipes whose water intake is controlled by a PLC.



Figure 3 - top view (left) and side view (right) of the green wall

## 5. METHODOLOGY USED

The basic principle for the acoustic assessment involved characterizing the sound environment of the street, before and after setting up the green wall. In order to do this, two types of tests were carried out, as described below.

### 5.1 Evaluation using the ambient noise level generated by street traffic

Two measurement stations placed on the 1st and 2nd floor respectively (PF1 and PF2 – cf. Figure 4) of the public library building facing the green wall were used to collect the acoustic signals continuously (Leq integration time: 1s) for a full week, before and after setting up the green wall. Alongside the acoustic signals, all traffic data on the road (number of light vehicles, HGVs, average traffic speeds) was collected using a traffic counter.



Figure 4 - Measuring stations PF1 and PF2

Before-and-after comparison of the noise environment was made after readjustment to acoustically equivalent traffic using the formula described in the French road noise measuring standard NF S 31-085 (6):

$$L_{Aeq,r\_with} = L_{Aeq,m\_with} + 10 \times \log \left( \frac{Q_{eq,without}}{Q_{eq,with}} \right) + 10 \times \log \left( \frac{V_{m,without}}{V_{m,with}} \right) \quad (1)$$

where:

$L_{Aeq,r\_with}$  = A-weighted equivalent sound pressure level, readjusted according to traffic conditions observed without the green wall.

$L_{Aeq,m\_with}$  = A-weighted equivalent sound pressure level, measured with the green wall.

$Q_{eq,with}$  = acoustically equivalent hourly rate measured with the green wall.

$Q_{eq,without}$  = acoustically equivalent hourly rate measured without the green wall.

$V_{m,with}$  = average speed of the flow of vehicles measured with the green wall.

$V_{m,without}$  = average speed of the flow of vehicles measured without the green wall.

with:

$$Q_{eq} = Q_{VL} + 12 \times Q_{PL} \quad (2)$$

where:

$Q_{VL}$  = flow of light vehicles

$Q_{PL}$  = flow of HGVs

## 5.2 Evaluation using a standard sound signal (pink noise)

The signal of the noise source, generated by an omnidirectional speaker to ensure homogeneous emission of sound in the street, was emitted in three locations S1, S2, S3 located around the retaining wall. The signal was collected on a mesh of receiver points (P1 to P7) around the site (Figure 5). The process was carried out before and after completion of the green wall. For both sets of measurements, several signal streams were emitted in order to obtain good reproducibility.

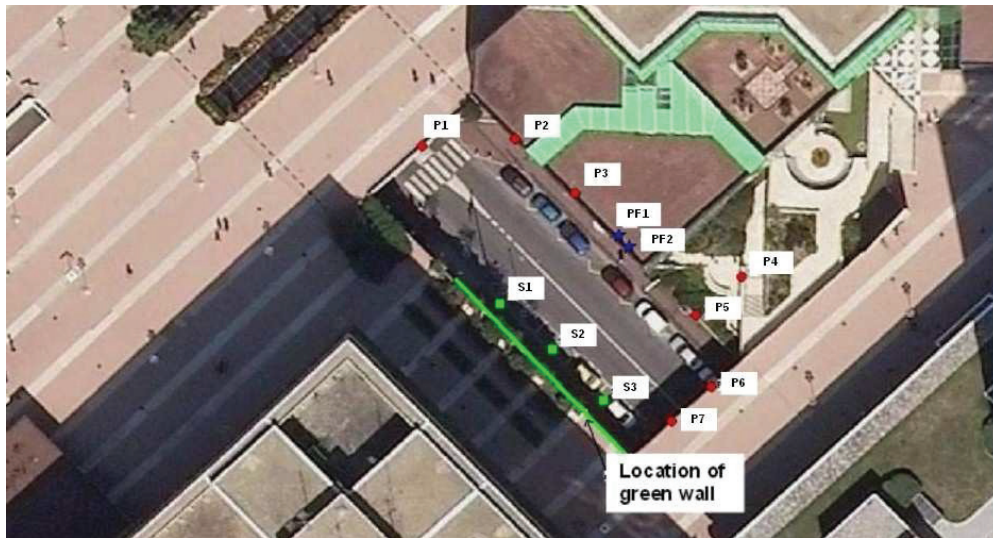


Figure 5 - Source/receiver locations (top view)

## 5.3 General considerations

As the purpose of the tests was to quantify the potential effects of setting up the green wall, the conclusions of this analysis should not be polluted by random effects falsifying the results, and by errors in judgement or manipulation by the operators making the measurements.

In order to minimize these errors, the following operational precautions were taken:

- exact dimensioning in three dimensions (x, y, z) of the *in situ* locations of the source and receivers in order to be able to repeat the measurements after setting up the wall in the same conditions as initially.
- although not used in terms of propagating effects given the short distances between sources and receivers, local weather data was collected. The aim was to identify any specific weather events that might interfere with the measurements.
- the same measuring chain (microphones, cables, sound level meters, acquisition card, sound source and speaker, etc.) was used for both measurement campaigns.
- for measurements using road traffic, the uncertainty related to using the readjustment formula of standard NFS 31-085 (6) was determined based on the typical uncertainty of the traffic counter used (uncertainty propagation calculation). It has been shown that the use of the readjustment formula leads to an uncertainty about the result of approximately 0.3 dBA ( $\Delta = + - 0.3$  dBA)
- compilation and analysis of results were managed by the same operator.

## 6. RESULTS AND ANALYSIS

### 6.1 Measurements of noise levels using traffic

The graphs below (Figure 6) describe the sound pressure levels during the day (between 6 am and 10 pm) for the two fixed points (PF1 and PF2) before and after setting up the green wall. Results are analysed day by day.

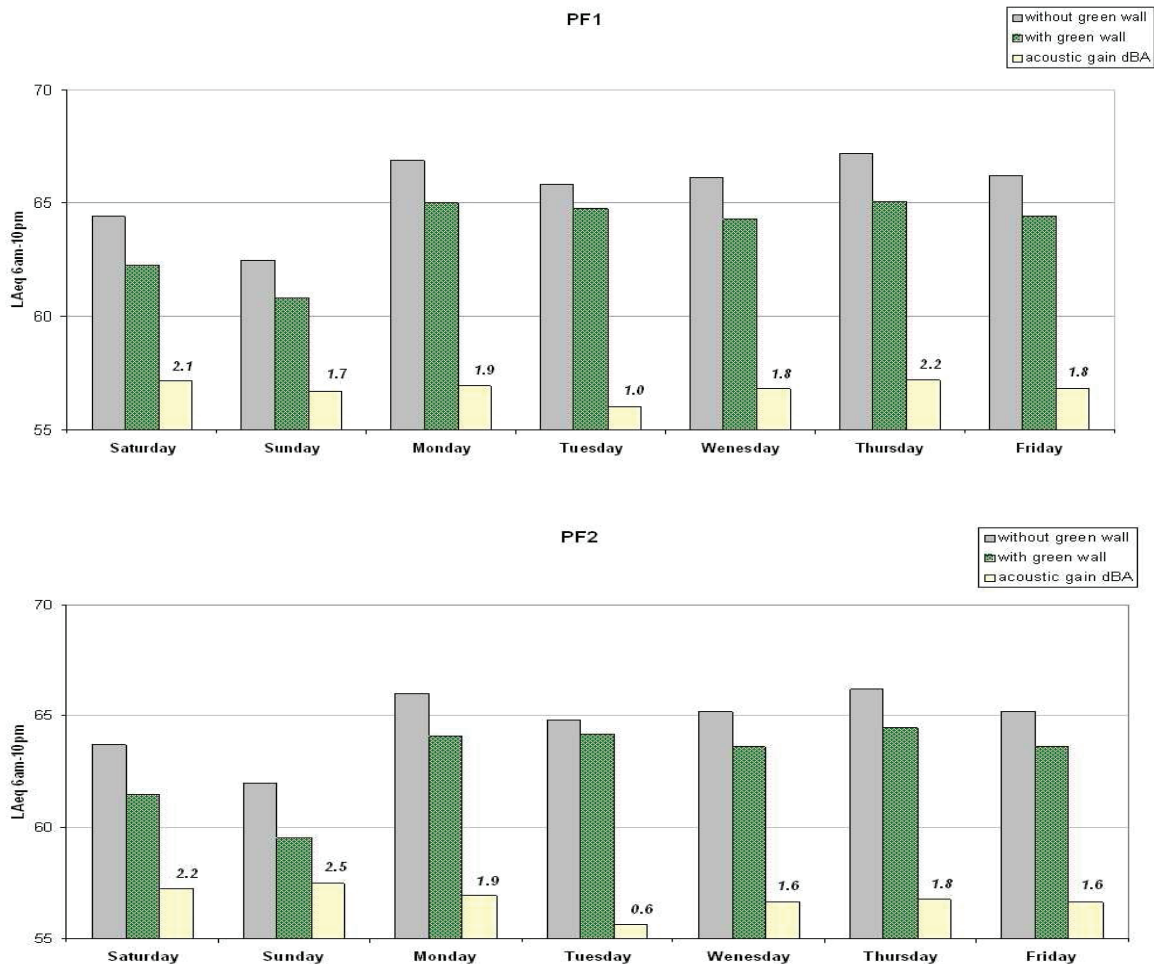


Figure 6 - comparative changes in  $L_{Aeq}$  6am-10pm over a week (before/after the green wall) at PF1 (top) and PF2 (bottom).

In general, for both fixed measurement points and in equivalent traffic conditions (see section 5 - Methodology), there is a decrease in overall sound pressure levels (dBA) generated by road traffic as a result of setting up the green wall on the site. Acoustic gains remain moderate and range from 0.6 to 2.5 dBA depending on the measurements day. A rather inconsistent gain value was recorded on the Tuesday. This phenomenon is explained by heavy rain in the morning of the Tuesday of the campaign carried out after setting up the wall, which led to an overall increase in sound pressure levels recorded that day.



## 6.2 Measurements of noise levels using a standard signal

### 6.2.1 Overall analysis (in dBA)

The results of the comparative study on overall sound levels recorded before and after setting up the natural covering and for different measurement configurations are shown below (Figure 7).

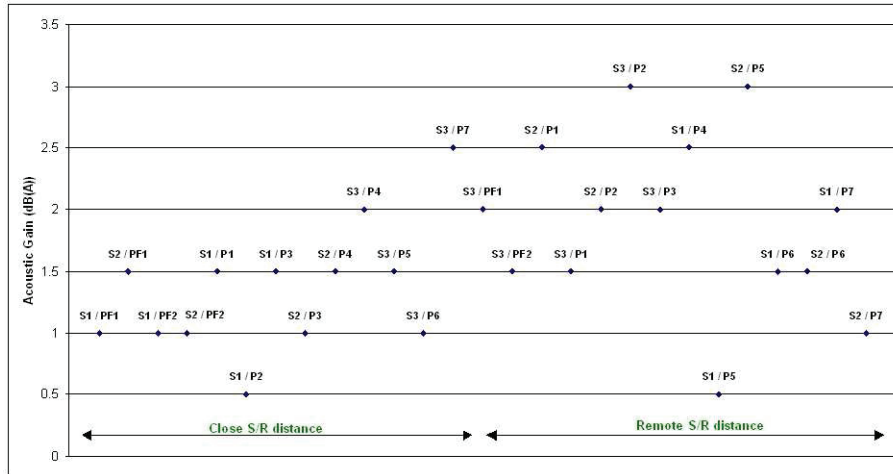


Figure 7 – Acoustic gain before/after the green wall for different source/receiver configurations

In general, the acoustic gains after setting up the green wall range from 0.5 to 3.0 dBA depending on the different source/receiver configurations. The most significant acoustic gains were recorded for configurations where the source is farthest from the receiver. These configurations are in fact less subject to the direct field of the source, since the "weight" of the reflected field is more important and then the influence of the green wall is more sensitive. Finally, these results are broadly consistent with the orders of magnitude of acoustic gains recorded *via* direct measurement of noise from road traffic (see section 6.1).

### 6.2.2 Spectral analysis

During the two measurement campaigns, each signal generation in the different source configurations was collected for each receivers locations (one-third octave spectrum). Figure 8 shows the comparative average spectra (before/after the green wall) for two representative source-receiver configurations (source and receiver distant from one another).



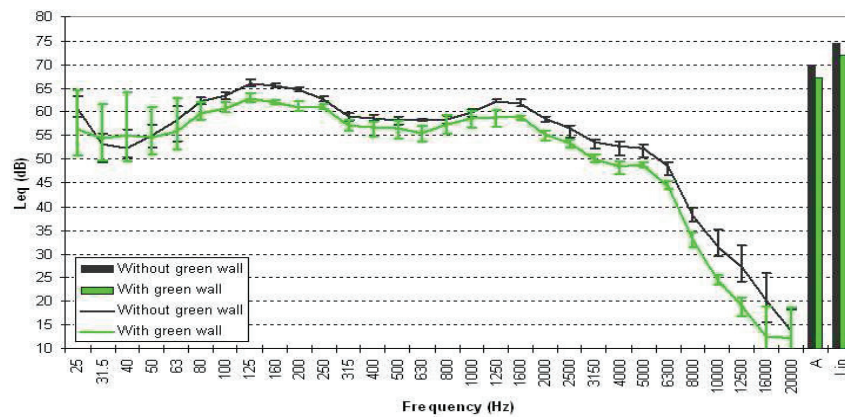


Figure 8 - comparative spectra before/after the green wall - S2P1 configuration (previous page) and S1P4 (above)

In general, and regardless the source/receiver configuration, a slight drop in one-third octave spectrum values measured in the presence of the green wall beyond 80-100 Hz is to be noted. Fairly obviously, acoustic gains per frequency band are relatively small or insignificant for configurations where the source is close to the receiver and where the impact of the green wall is null (e.g. S1P1, S1P2, S3P6).

In the middle frequencies (400 - 2500 Hz), acoustic gains are moderate (between 0 and 6 dB depending on the configuration and the one-third octave band concerned) with maximum efficiency for configurations where the source is distant from the receiver (S1P4, S2P2, S2P1, S1P7).

At high frequencies (3150 to 20000Hz), except for close source/receiver configurations, acoustic gains are substantial (between 0 and 10 dB depending on the configuration and the one-third octave band concerned).

## 7. CONCLUSIONS

The overall results of this study show that green devices tend to reduce moderately sound pressure levels on façades in streets. Moderate noise reductions in the middle frequencies (400-2500 Hz) can be observed; these can be attributed to acoustic absorption due to the planting substrate. Efficiency is greatest at high frequencies (above 3150 Hz) where a scattering phenomenon caused by the foliage of the development also comes into play. However, the acoustic gains obtained are very variable according to the configurations and/or periods of measurement, which does not make it possible to pass any judgement as to the effective efficiency of the system.

The green development considered in this analysis is an evolving system (the substrate changes, the root system develops within the substrate, and the surface foliage increases), in contrast to a conventional sound absorber which is more stable over time. The question of the sustainability of the acoustic characteristics of such an infrastructure may be considered.

The results of this study are of course limited to the test site with its own characteristics. Results may be significantly related to the total surface area of the wall and the street dimensions. Thus it seems quite appropriate to extend the experiment to other sites with different characteristics and/or hosting different systems in order to improve and refine this initial analysis.

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