Acoustic Design #02 : Urban Acoustics
Free field Propagation

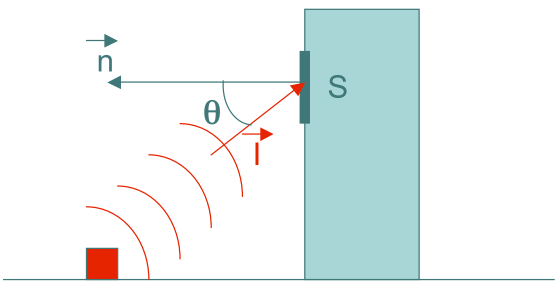
Definition

1- Power level (in dB or dB(A))

$$Lw = 10\log\frac{W}{W_0}$$

with
. W, acoustic power of the source
. W_0, acoustic reference power = 10^{-12} watts

1- Acoustic intensity (en W/m²)

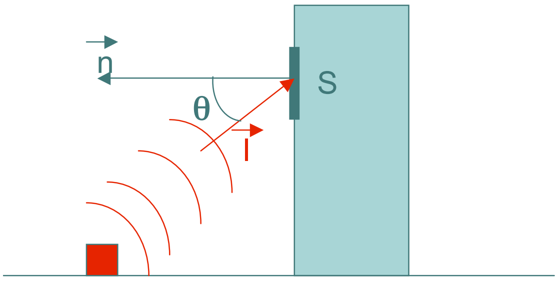


$$W = I \times S \times \cos\theta$$

with
. W, acoustic power that pass through the area S
. I, acoustic intensity of the source
. θ, angle between the normal to S and the main direction of acoustic waves

Definition

2- Acoustic intensity (en W/m²)



$$W = I \times S \times \cos\theta$$

with
. W, acoustic power that pass thought the surface S
. I, acoustic intensity of the source
. θ, angle between the normal to S and the main direction of acoustic waves

That is to say, acoustic intensity is defined as a vector :
- it has a direction and a way (the ones of the acoustic waves)
- a value that represent the energy that propagates expressed in Watt/m²

If the wave hit perpendicularly the surface, cosinus value is 1 (maximum). So, the use of cosinus in this formula characterise the relative incidence between the surface ant the acoustic waves.

Definition

3- Level of acoustic intensity (in dB or dB(A))

$$L_I = 10\log\frac{I}{I_0}$$

with
. I, acoustic intensity of the source
. $I_{0,}$ referential acoustic intensity = 10^{-12} watts

BE careful to vocabulary ! You should not make the confusion between
. Acoustic power (**W**, en watts) and the level of acoustic power (**Lw**, in dB)
. Acoustic pressure (**P**, en Pascal) and the sound pressure level (**SPL or Lp**, in dB)
. Acoustic intensity (**I**, en W/m²) and the level of acoustic intensity(**$L_{I,}$** en dB)

What we hear, or what we measure, it's the sound pressure level (SPL) express **in dB or in decibel A [dB(A)]**

So all acoustic problems aims to link the Sound Pressure level (SPLor Lp) with the acoustic power (Lw) of the source using the acoustic intensity (LI) as an help for calculation.

Plan wave

1- link between L_I, Lp et Lw

We can show that for a plan wave, we have

$$I = \frac{P^2}{\rho c}$$

with
. P^2, efficient acoustic in Pascal
. ρ, density of air = 1,16Kg/m3
. c, speed of sound = 342m/s

If we form the following ratio (I/I0) et P^2/P_0^2, we show the equality :

$$\frac{I}{I_0} = \frac{P^2}{40010^{-2}} = \frac{P^2}{4.10^{-2}}$$

$$\frac{P^2}{P_0^2} = \frac{P^2}{(2.10^{-5})^2} = \frac{P^2}{4.10^{-2}}$$

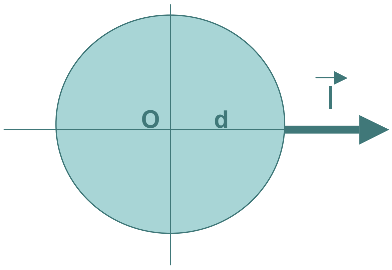
And then, il we take the 10log of each part of the equality, we demonstrated that for a plane wave, we have :

L_I = Lp

Plan wave

2- omnidirectionnal source in a free field

We imagine an omnidirectionnal source that emits acoustic power W equal at the one which pass trough a sphere with radius d



By definition, acoustic power is :

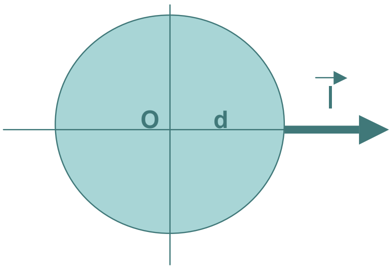
$$dW = \int_s I\,dS$$

$$W = I.\int_s dS$$

$$W = I.4\pi d^2$$

Plan wave

2- omnidirectionnal source in a free field



Then… :

$$\frac{W}{10^{-12}} = \frac{I}{10^{-12}} 4\pi d^2$$

$$10\log\left(\frac{W}{10^{-12}}\right) = 10\log\left(\frac{I}{10^{-12}} 4\pi d^2\right)$$

$$Lw = 10\log\left(\frac{I}{10^{-12}}\right) + 10\log(4\pi d^2)$$

$$Lw = L_I + 10\log(4\pi d^2)$$

avec

$$L_I = Lp$$

$$Lp = Lw - 10\log(4\pi d^2)$$

** When d is big, we can consider that, locally, the spherical sphere is like a plan wave*

Plan wave

2- omnidirectionnal source in a free field

If the source is closed by one obstacle (plan, angle…), the reflect wave is not spherical anymore. We need to correct the acoustic pressure (or the intensity) by a factor, named directivity factor Q.

$$\boxed{Lp = Lw + 10\log\frac{Q}{4\pi d^2}}$$

en dB(A)

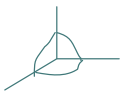
with Q

Q = 1, omnidirectionnal

Q = 2, omni on a floor

Q = 4, omni in an angle diedre

Q = 8, omni in an angle triedre.

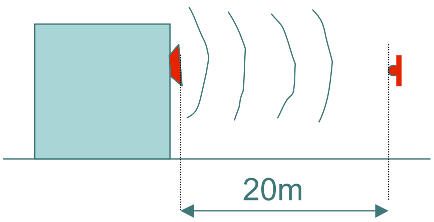


Plan wave

2- omnidirectionnal source in a free field

$$Lp = Lw + 10\log\frac{Q}{4\pi\, d^2}$$ en dB(A)

Example: what is the sound level pressure of a air conditioning as described on the following drawing ? Lw = 80 dB(A).



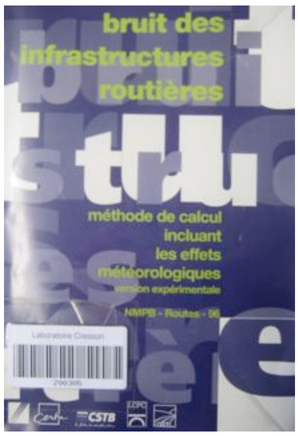
$$Lp = Lw + 10\log\frac{Q}{4\pi\, d^2}$$

$$Lp = 80 + 10\log\frac{2}{4\pi .20^2}$$

$$Lp = 46dB(A)$$

Plan wave

2- omnidirectionnal source in a free field



$$Lp = Lw + 10\log\frac{Q}{4\pi\, d^2}$$ en dB(A)

Be carreful, this formula can be used only with a distance under 120m

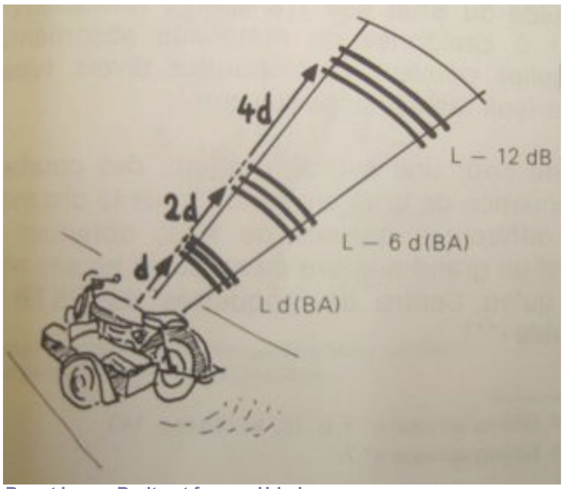
After 120m, we can't miss :
- **type of floor (concrete, earth, grass…)**
- **air humidity** : sound level pressure rise with humidity (except snow and fog)
- **air temperature** : SPL rise a little with temperature

-wind

Modification of SPK in dB(A)	d=100m	d=500m	d=1000m
with the wind	+0,5 à 1	+1	+4 à 5
against the wind	-5 à -10	-16	-20

Plan wave

2- omnidirectionnal source in a free field



Bar et Loye - Bruits et formes Urbaines

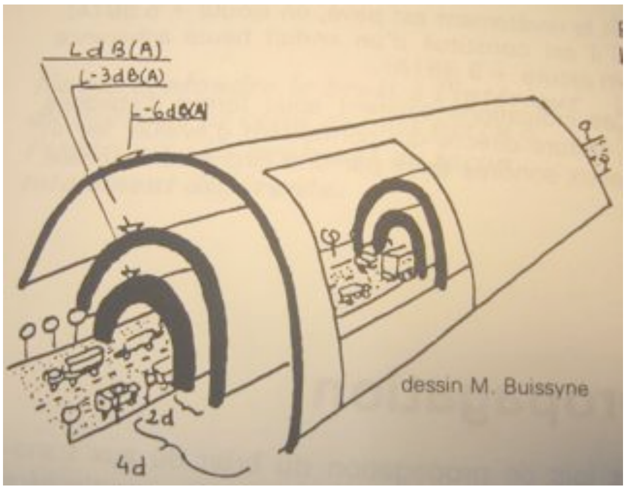
In free field, omnidirectionnal source decrease :

- 6dB(A)/ each time we double the distance

example
Si Lp = 75 dB(A) at 10m
so
Lp = 69 dB(A) at 20m
Lp = 63 dB(A) at 40m
Lp = 57 dB(A) at 80m
etc…

Plan wave

2- half cylindrical source in a free field



Bar et Loye - Bruits et formes Urbaines

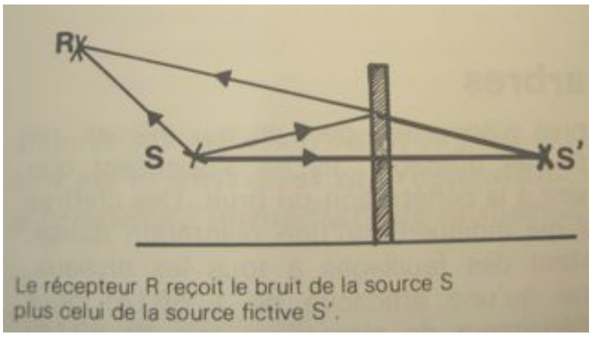
In free field, one linear source decrease :

- 3dB(A)/ each time we double the distance

exemple
Si Lp = 75 dB(A) at 10m
so
Lp = 72 dB(A) at 20m
Lp = 69 dB(A) at 40m
Lp = 66 dB(A) at 80m
etc…

Plan wave

3- Plan Wave in front a rigid plan



Reception point (R) receive acoustic energy from the source (S) and from the virtual source S'… as the reception R is actually receiving the contribution of 2 sound sources : + 3dB(A)

(likes in optics)

Bar et Loye - Bruits et formes Urbaines

Noise treatment in free field

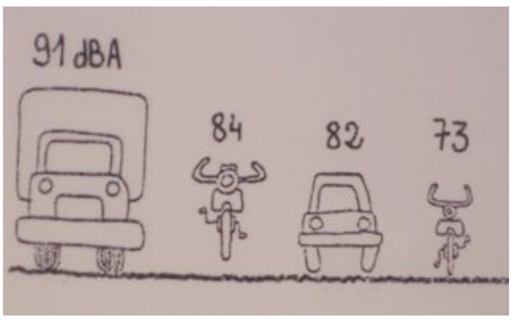
1- Reduce the source

Mains works are on :

1. engine noise but more researches are developed to reduce noise contact of tires with the asphalt. .
2. find silent asphalt (with good characteristics drain water, toughness, etc..)
3. move traffic
4. reduce speed limitation

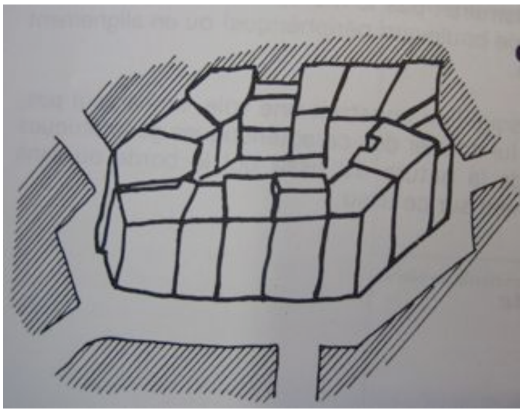
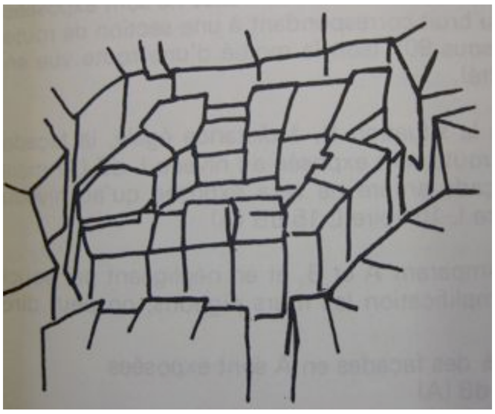
- For planes, “agreements” are signed with residential areas (mayor) and direction of the airport (number of flight, land in land off trajectory

- Trains are often less noisy for people because of the duration of noise.
- Except for high speed train when they pass close to houses at the maximum of speed (300km/s)
- More researches are developed in railway station (when the train breaks) or to improve acoustic comfort inside the wagon.



Noise treatment in free field

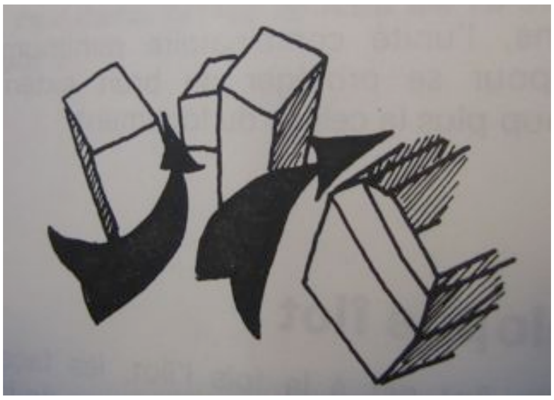
2- Urban forms and « natural acoustic protection »

Noise treatment in free field

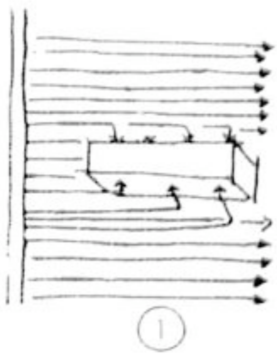
2- Urban forms and « sonic porosity »

Analogy with wind phenomena

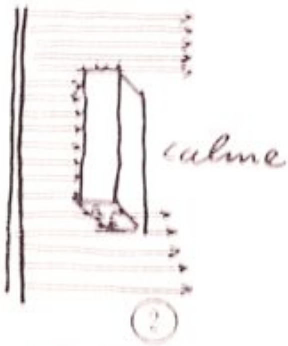


Noise treatment in free field

3- Reduce the number of exposed faces of the building



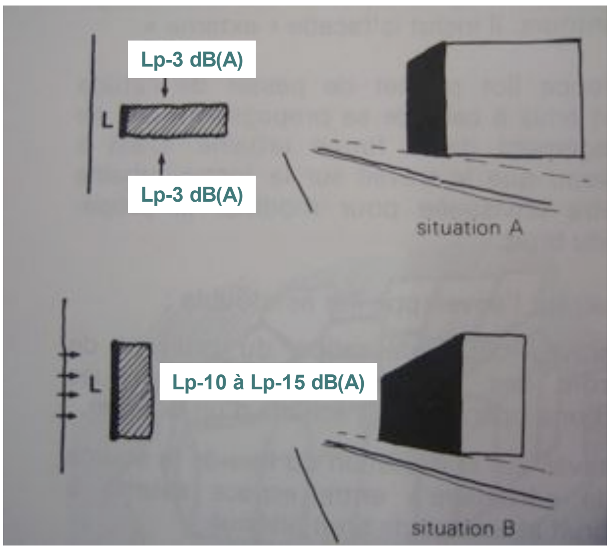
2 main faces are equally exposed.



One of tne main face is not exposed

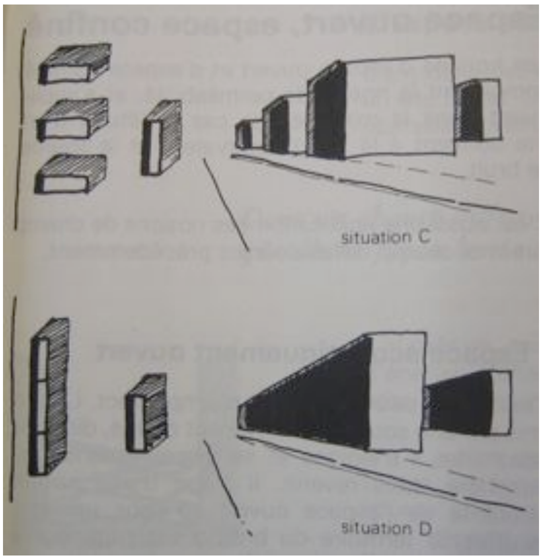
Noise treatment in free field

3- Reduce the number of exposed faces of the building



Noise treatment in free field

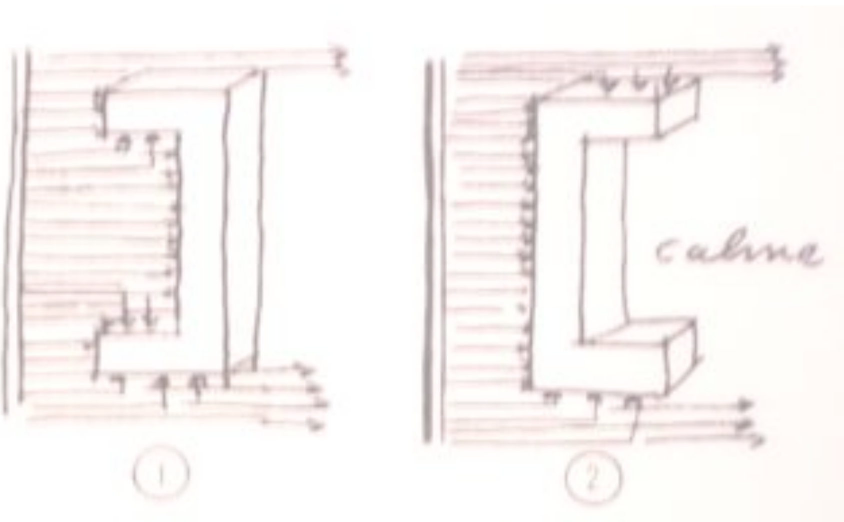
3- Reduce the number of exposed faces of the building



• Situation C is more permeable than the situation D.
• Situation D can protect more apartments or rooms
but
• it's also the situation that shows to road (noisy face) the maximum of rooms.

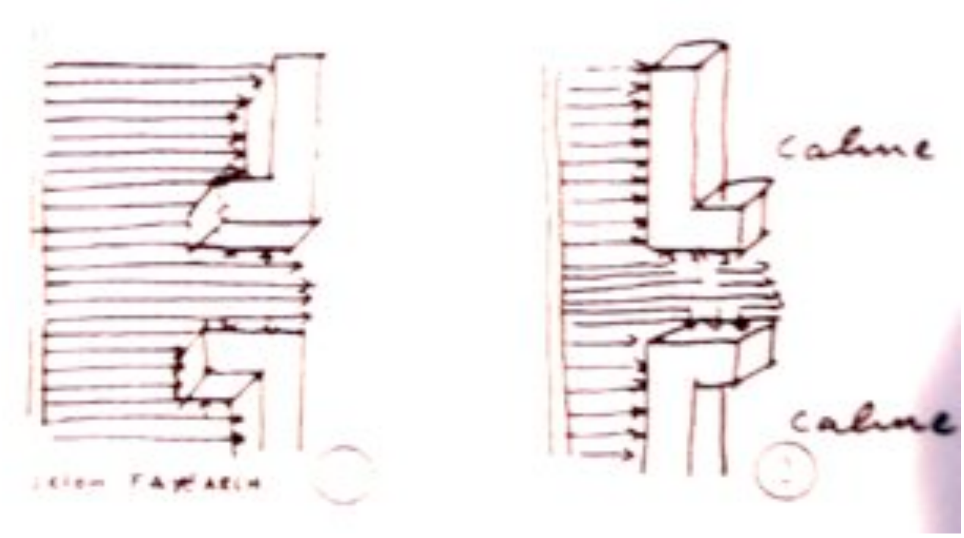
Noise treatment in free field

3- Reduce the number of exposed faces of the building



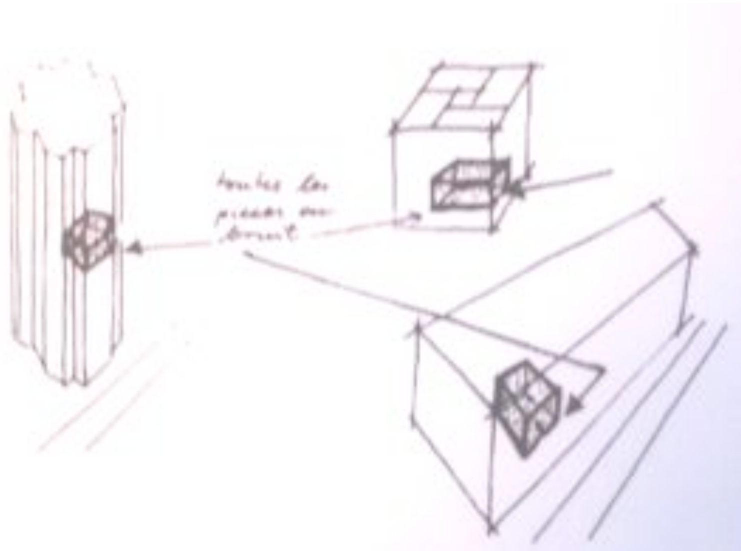
Noise treatment in free field

3- Reduce the number of exposed faces of the building



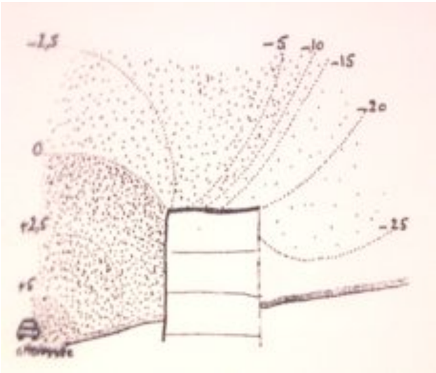
Noise treatment in free field

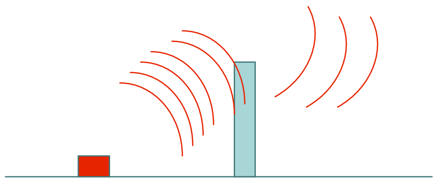
4- Organise rooms and apartments depending on the noise exposure



Noise treatment in free field

5- Diffraction of soundwaves



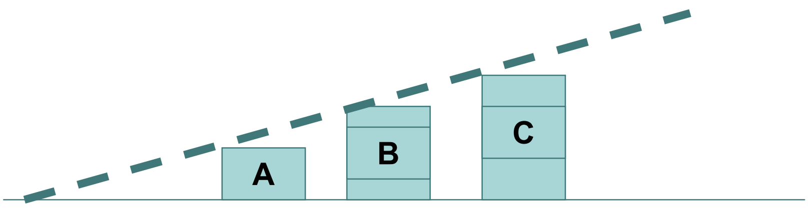


The obstacle top emits sound wave as a source

Noise treatment in free field

4- « Epannelage »

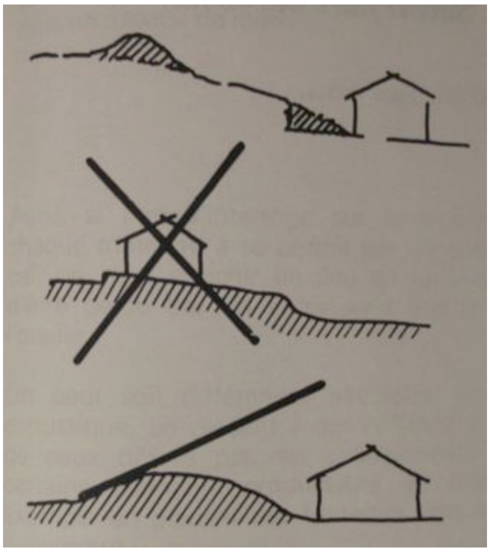
A protect B
B protect C
…



Noise treatment in free field

5- Natural protections

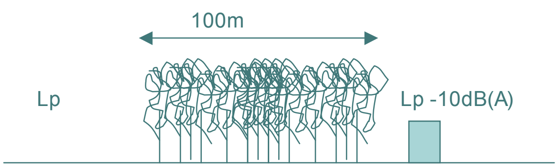
The distance from the noise doesn't count.
The natural small hill is obviously fundamental



Noise treatment in free field

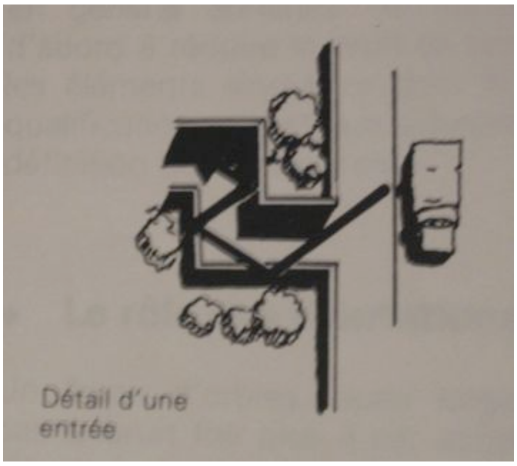
5- Natural protections

You need **100m of a forest with dense vegetation to gain 10dB(A) of the sound level decrease**



Noise treatment in free field

6- Create artificial barriers



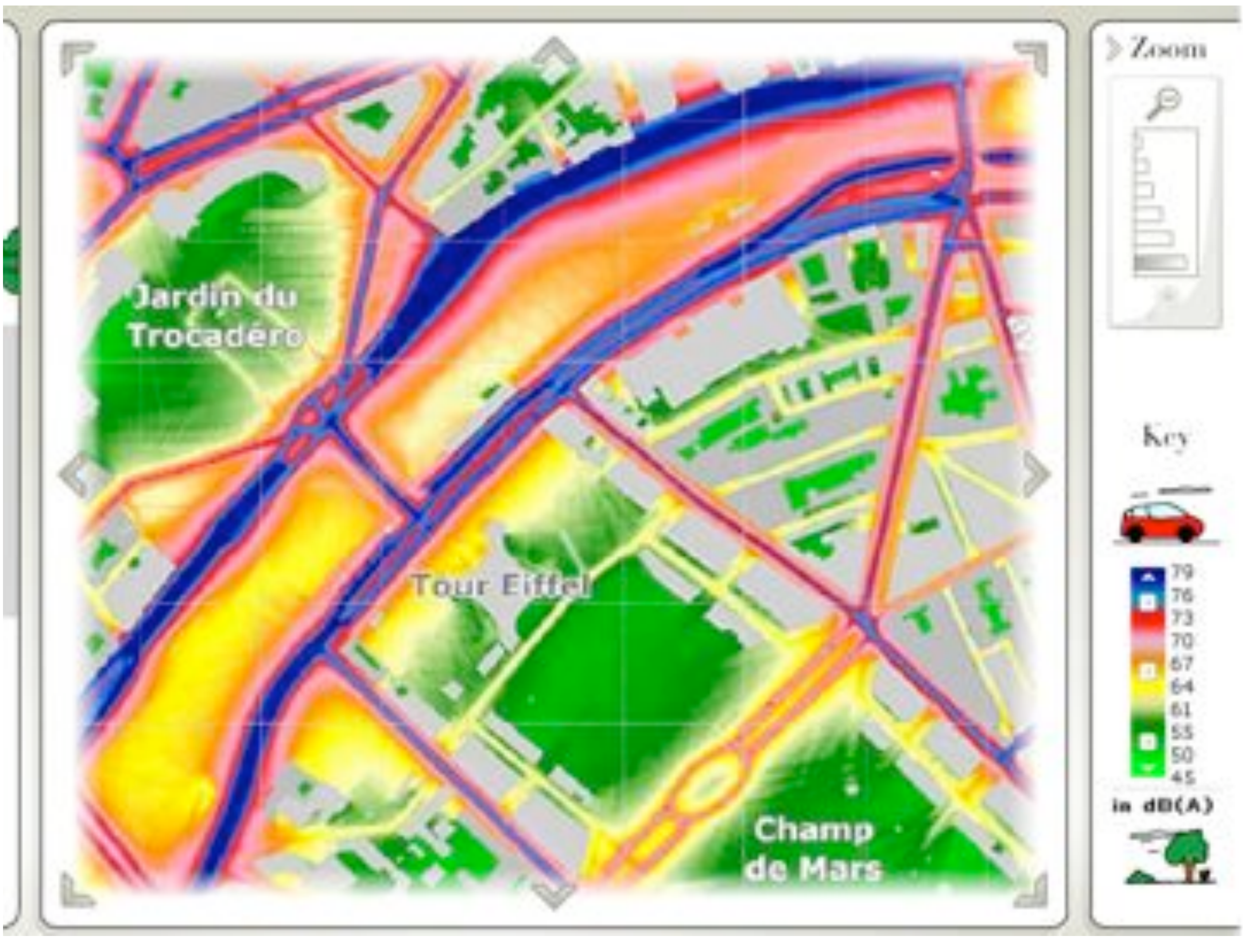
Be Careful !
. The efficiency of a good noise barrier is around 7dB(A).
That is to say :
•-3, -3 and -1dB … sound level divided by 4
But
• it's not -10dB(A) as excepted by inhabitants.

Example - Παράδειγμα

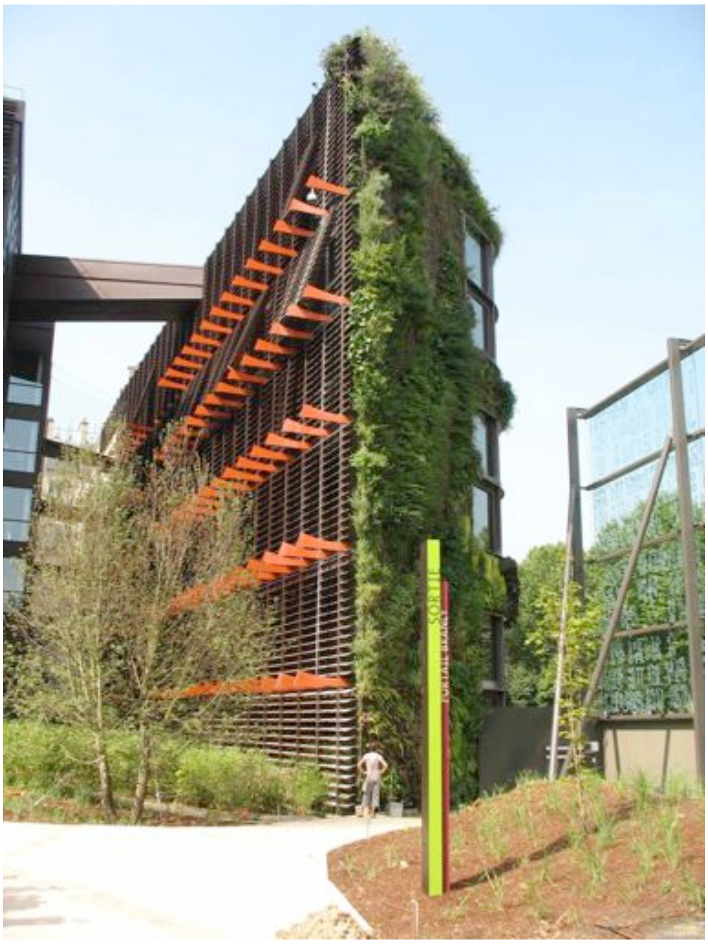
Musée des Arts premiers ou Musée du Quai Branly, Paris - Μουσείο Πρωτόγονvων Τεχνών

Jean Nouvel, Architect


Vue aérienne
Plan simplifié
Plan détaillé
GROS CAILLOU 7ART
mètres


Jardin du Trocadéro
Tour Eiffel
Champ de Mars
Zoom
Key
79
76
73
70
67
64
61
55
50
45
in dB(A)

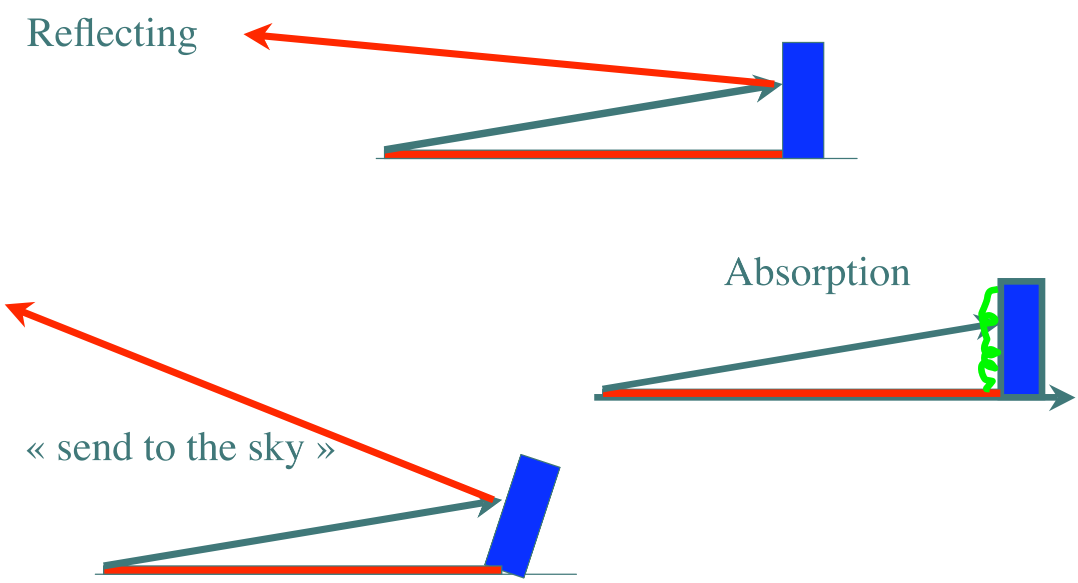

S
E
W
N
Façades facing the NORTH
Zoom
Key
79
76
73
70
67
64
61
55
50
45
in dB(A)


SORTIE

Noise treatment in free field

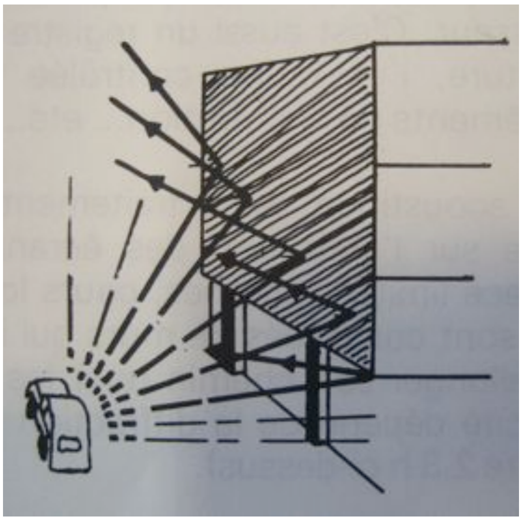
6- Noise barriers

3 basic principles



Noise treatment in free field

7- Building faces treatments

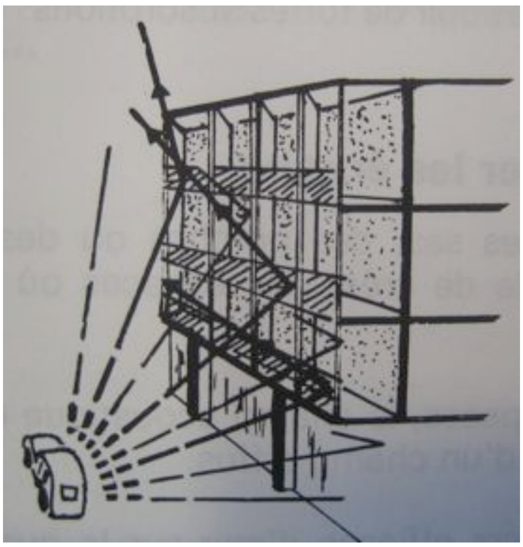


To use building « thickness » (multiply skins of the buildings)

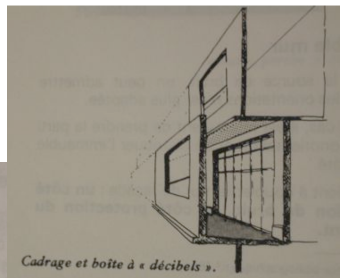
Oppose to the noise the weight of the building

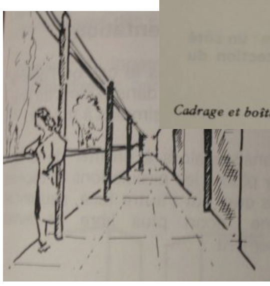
Noise treatment in free field

7- Organise rooms and apartments to create « tampon zone »



Balcons, loggias, coursives, escaliers intérieurs … tout espace tampon dont on traitera l'efficacité acoustique.

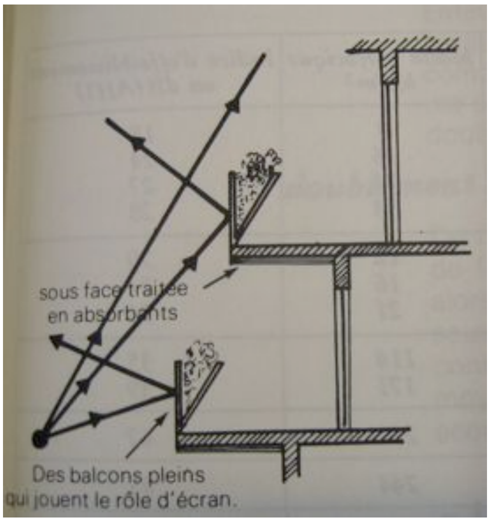




Bar et Loye - Bruits et formes Urbaines

Noise treatment in free field

7- Balconies - details



Thickness of « garde-corpts » can also be full and protect from the noise.

The under face of balconies can also be treated.

To remind

. 1 (one) decibel weighted A or 1 dB(A) is the smallest unit that human ear can hear (it's theoretical and you can prove it inside a very silent place like a studio or under headphones)

. In ordinary life, we realise that sound level has changed if we're in front an increase or an decrease about 3dB(A)… that means is the sound level has been, physically, increased or decreased by 2.

. When you double the sound sources, the SPL increase about 3dB(A)

. In the other way, if you divide by 2 the number of sources, the SPL decrease about 3dB(A)

. BUT, in practice,, to have the « feeling » that sound level has been decrease about 10dB(A), you have to decrease, physically, the SPL about 10dB(A).

. Each time you double the distance, a omnidirectionnal source lose 6dB(A)

. Each time you double the distance, a linear source lose 3dB(A)