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Offices and dwellings: what building acoustics for sustainable development?

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Sustainability has proved to be a major concern since the beginning of this century. Among the 14 targets for sustainable projects as defined in the French standards, one specifically deals with acoustic comfort. Over the years, those standards have been developed to cope with various kinds of buildings. However, due to the lack of discussion between specialists it has sometimes proven hard to be applied. Furthermore, a lack of coherence may sometimes appear between sustainable standards by HQE, national standards by AFNOR, and national regulations. This paper aims to submit a few questions on those matters.

1 Introduction

Sustainability is first of all a fashionable way to design a building and help promote a nice image of the end user of the building. Or is it something else? Perhaps a way of saving on maintenance and operating costs later on? There undoubtedly is a mixture of those, together with the advertised aim of saving the planet's resources [1].

Sustainability has several aspects linked to acoustics: there of course is the design of the building proper (i.e. having a good acoustic quality inside the premises), but there also is a notion of preventing noise pollution originating from the building operation as well as preventing noise pollution from the construction. Over the years, this has led to several standards [2,3,4] covering those various aspects. As the committees involved in drafting those standards seldom featured acousticians actively participating in defining the targets, the first experimental standards were something full of good will but often quite unpractical. As an example, the first experimental guidelines by HQE on office buildings stated that the background noise level in a highly performing office room should not exceed 25 dB(A) [5], which was economically unsound, technically unrealistic, and physically unsatisfactory.

As experience grew in this field, it was possible to adjust the targets accordingly. Yet, from a sustainable compliant building to a satisfactory (for the users, that is) building, there still can be a quite significant gap, as will be seen in the next chapter. One might keep in mind that the higher the targets, does not always mean the better the feeling of the inhabitants or users!

Sustainability is of course not exclusively devoted to acoustics, e.g. it also covers thermal and visual aspects, as well as the nature of the materials that are used in the construction process. This often prompts with the end user a fear of anything fibrous. Even with the relevant environmental certificates at hand, it does take some time for the idea of an eventual use of fibrous materials to sink in (with of course the economist the first to come to sense when seeing the costs involved in most ersatz materials).

The fore basic idea in a sustainable building operation is for every member of the design team to speak to each other. This is an absolute necessity as most building fields will interact between each others [6]. The specialist in sustainability hired in the team is supposed to coordinate the team in this respect. Unfortunately, such a specialist might be an economist or architect who has been rather hastily trained in the field of sustainability and who is blatantly ignorant of standards and implications the moment it lies out of their normal line of work. While they are fully trained to ask for the relevant administrative papers (e.g. environmental certificates of materials or formal calculation), they are unable to weight the advantages and inconveniences of, e.g., a given strategy favouring either acoustics or thermal aspects.

This means that early enough in the project, a sound discussion must be carried out between all members of the design team as well as with the end user to define what are the top priorities regarding the various targets of the sustainable building. Then, decisions will have to be taken on the basis of a vigilant diagnosis of both premises (if existing) and working / living habits that will be carried out prior to any attempt at dimensioning a new project.

2 Diagnosis

The diagnosis is an important tool of the acoustical engineer. First of all, it is meant to provide him with an insight of the working and living conditions of the end user. Next, whenever there are existing premises, it is meant to determine their acoustical performance so as to provide a reference.

2.1 Assessing the working or living conditions: why

Assessing the working and/or living conditions of the end user helps find out what is considered important (one might kindly remember that the performance of the building might be important to the investor, but it is the actual feeling of comfort that will be important to the end user; this means that the end user must ultimately be able to indulge in his habits in the new premises that will be built).

Such a diagnosis will of course feature acoustical measurements (e.g. ambient noise at the workplace, noise emitted by the activities or equipment, sound attenuation with regards to other workstations or living spaces, etc.). But it is quite important to perform a work or behavior analysis through a vigilant observation in order to pick out key features that will help dimension the acoustic objectives later on. In addition, questions can be asked to the interested parties.

2.2 Assessing the performance of the existing premises: why

Assessing the performance of the existing premises in which the end user is currently evolving helps find out what is to be the basic minimum performance (as it is of course out of the question to propose lesser quality in the new project).

Such a diagnosis will of course feature acoustical measurements (e.g. sound insulation, background noise, reverberation time, etc.) inside the premises.

In addition, such a diagnosis can serve as a reminder later on should one complain of poorer acoustical performance than before.

2.3 Assessing the performance of the environment: why

Assessing the performance of the existing environment might seem out of focus, as the construction project will probably change quite a few things around.

However, there are many reasons for the design team to find out what the acoustical environment of the project might be. To start with, there might be some potential environmental noise sources around, some as obvious as transportation corridors, and others less obvious like a leisure facility. But there might also be some sensible spaces close by, like dwellings, or even a mixture of both aspects (e.g. a school, which needs protection from undue noise but that can also generate high noise levels at break time). All those aspects must be investigated in order to properly dimension the noise emission of the future project.

But before that future project is actually completed, there will be a period of time for construction. Even worse, there may be a period of time for deconstruction should the site be occupied by the remnants of an existing construction. The results of the environmental diagnosis will be a key to the choice of construction and deconstruction methods to be used [9].

3 Target definition

3.1 Sustainability and its format

Sustainability usually calls for a specific format regarding the calculation notes and the data presentation. While this is useful for the examiner who will ultimately decide on the eligibility of a given project to a sustainable building label, such a format may draw the attention away from sensible subjects (especially the actual suitability of the premises to the future end user).

3.2 Standards

Sustainability requirements are typically covered in standards [2,3,4]. Regarding the acoustics, those standards typically feature requirements on sound insulation to the outside (preventing noise from entering the premises), sound insulation between rooms, reverberation control, mechanical equipment noise and vibration control, as well as some more general aspects (e.g. proving that the design has judiciously implemented rooms with regards to each others).

While those standards give numeral values, it should not be forgotten that some other aspects may apply too (e.g. guidelines on noise at work, regulations, etc.).

While the French HQE devotes its target 9 fully to acoustic aspects, it also introduces some acoustic requirements in target 3 regarding the noise reduction of construction noise. Unfortunately, this is often forgotten due to these requirements being lost amid various requirements on rubbish elimination measures [2]. The HQE is currently being revised in order to offer better flexibility and understanding to the user [8].

The British BREEAM features two specific requirements on acoustics: item Hea13 covers internal acoustics inside the premises as an health problem, while item Pol8 covers all noise emission aspects into the environment [3]. Interestingly enough, the criteria of Pol8 happens to be the one that was recommended in an old

advisory text of the French Health Ministry [10]: it is stated that the gap between the noise level with the project operating and the background noise level without the project should not exceed 3 dB(A). Regarding the ambient noise inside the premises and the sound isolation between rooms, BREEAM offers a rather simple and nice approach by requiring that the sum of the sound isolation D_w plus the equivalent ambient sound level $L_{Aeq,T}$ should be greater than 75 dB.

BREEAM does imply quite a number of verifications by the expert on completion of the project.

3.3 Setting the objectives

According to the targeted level of performance, the acoustic objectives will be set. One should be aware that it is not a mere matter of putting figures in a table as it will have consequences later on the living conditions inside the premises. Experience should be drawn from the results of the diagnosis and checked against other specialists' analysis.

A good set of acoustic objectives is one that preserves the equilibrium between the various contributions to the global noise inside the premises: noise from the exterior, noise from neighbouring spaces, mechanical noise (HVAC), office equipment noise, and noise from human activities [7].

A decision with heavy acoustical consequences will be that of using the thermal inertia of the building. Whenever this happens, a sizable part of the ceiling is no longer available for acoustical purposes and it then becomes hard to achieve a satisfactory spatial sound level decay. More to the point, this is often in contradiction with the acoustical guidelines of sustainability standards! It does take some convincing talk to the HVAC specialist to get him into admitting that a ceiling can actually be suspended under part of the upper floor.

It is of course possible to apply for a given environmental certification (e.g. HQE in France), or even for several certifications (e.g. HQE and BREEAM).

4 Design and construction

4.1 Regular process

As fathered, the sustainable building concept calls for all design team member to exchange on a regular basis (well, let's face it: that is what one should do in any project anyway!). The various stages of design and construction will be carried out properly in the respect of the initial objectives.

4.2 Deviating from track

Unfortunately, the end user or the investor may well discover that the sustainable building is not just a mere posture. It implies means to satisfy the various targets, and those have a cost. It means that by and by should the targets be kept the cost will rise, unless of course some targets are downgraded to lesser performance levels, which happens a bit too often for comfort when it comes to acoustics.

From sheer experience, this is what often happens, and quite often an end user will brief the design team that while he wants a design and construction process being as close as possible to the one recommended in the sustainability standards, he certainly will steer clear from any attempt at a

sustainable building certification, as this would ultimately create economical problems.

4.3 Fiber or not fiber

The moment the acoustical engineer expresses his wish for fibrous materials either as an absorptive treatment or as a partition filler, there usually are quite a few reactions. To start with, there are anxious people wondering aloud whether those materials will not prove to be a health hazard. One should better have the environmental data sheets and certificates handy! Next, the HVAC engineer will often complain about the undue extra thermal insulation.

Last, the end user may grow wary of the bad image given to his premises by the presence of fibrous materials and ask for a substitute material. Such a request usually ends the moment the extra cost involved is announced.

5 Case studies

5.1 Refurbished office building

This project illustrates an unfortunately typical pattern of so called sustainable buildings. A large company decided to refurbish a large office facility dating back to the 1970s. It was decided that the acoustic target would be ranked "very high performance". The initial diagnosis showed that while the façade sound insulation was good, it was achieved using single glass panes, with poor thermal performance.

The directors decided that most spaces would be of the open space type. This meant that highly absorptive ceilings were needed, and the budget was set accordingly. Unfortunately, this was decided without the end user being invited in the discussion. It turned out that most workers actually needed a partitioned office; unfortunately the height between floors was quite high and it was near to impossible to erect sound barriers over the now numerous partitions. A compromise was eventually reached but the acoustic quality gradually sank from "very high performance" to "basic performance" because of cost control.

5.2 Office tower (successful)

A large company decided to erect an office tower (36 floors) as a sustainable building. Due to the acoustic requirements of such a project, the background noise levels inside the premises were kept to a rather low value (i.e. typically 38 dB(A) in open spaces [8], which at any rate was much better than the 25 dB(A) initially sought [5]!). While this complied with the sustainability standard, it turned out to be a mess with the occupants as any unwanted sound (e.g. door slamming, people talking) was heard all over the premises.

So the situation eventually was that while the end user had a certified sustainable office tower, the occupants were clearly unsatisfied with it. A careful diagnosis including numerous talks with the workers pointed out that first of all the background noise levels were too low to be of any use as an effective masking noise. More to the point the importance given to natural lighting had precluded the application of absorptive barriers that could have helped improve the acoustic climate. In addition, a poor work analysis had led to the false impression that it was possible

to group any kind of people together in the same open space; the results clearly indicated that whenever there was more than one team in an open space there was trouble which was expressed as a complaint against noise.

5.3 Office tower (failed)

This particular project illustrates rather well how sustainability concepts can ruin a project should they be badly interpreted. An investor decided to have an office tower build with the sustainability label HQE. The architect happily complied and decided that one of the first moves would be to get rid of anything "false", i.e. no false ceiling (otherwise known as suspended ceiling), no false floor (technical floor). Incidentally, acoustics was targeted as "basic performance". In addition, the architect boasted that there would be the barest possible fibrous materials in his project. More to the point, by getting rid of "false" elements he was eventually inserting one more floor over the height of the building and could enjoy the thermal inertia of the building.

Unfortunately, there is an acoustic requirement for sustainable offices which states that the equivalent absorptive area should be at least 60% of the surface of the floor [8]. Due to the limited available height and thermal inertia policy, it was not possible to implement horizontally suspended elements under the upper floor and the whole project had to be drafted again, this time with some more understanding of each technical constraint.

In addition, that particular project was located downtown amid various dwellings. More to the point, the site featured an existing office building that had to be deconstructed prior to the erection of the new project. This deconstruction had been carried out as an independent project. While several specific measures were carried out regarding the sorting of waste material and the reduction of dust emission of vehicle exiting the site, the specifications regarding noise control were limited to the mere indication in the environmental assessment that the L_{Aeq} at the border of the site should not exceed 85 dB(A), without any further indication pertaining to the applicable span of time. To the consternation of the noise control engineer in charge of the project, the environmental assessor actually appeared ready to keep this noise limit specification for the construction project proper, on the grounds that it had been accepted before.

5.4 Dwellings

An architect managed to convince the township investing in a dwelling project that it could be built as a wooden construction. The mayor was especially pleased as this really would look as a sustainable building. The architect was careful enough to have specialist engineers tackling such specific points as acoustics and thermal aspects.

Unfortunately when the project was drafted the technical controller was full of questions and scornful remarks on the air of "never seen that one before so we will not accept it no matter what". Even with laboratory tests performed on the assembly and a full size mockup to prove the concept, the technical controller did not budge.

6 Conclusions

For sustainability to be more than a posture, one must first of all try and set objectives that will answer the end user's needs. Hiding behind the various sustainability standards will not do.

This means that first of all the needs and habits of the end user must be determined through a diagnosis and a questionnaire (work analysis). Then, the results from the various specialists can be crossed checked, targets set, and a sustainable project elaborated through discussions with all interested parties.

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