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ARCHITECTURAL MEASURES AIMED AT SOLVING THE PROBLEM OF AIRCRAFT NOISE IN BUILDINGS

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ABSTRACT
Coinciding with the start of construction of the new extension of Barcelona airport (El Prat), the Executive Office of the Barcelona Plan (OEPB), depending on Spanish Airports and Air Navigation (AENA), was set up to manage all works related to this extension. The OEPB developed a specific Plan for Acoustic Insulation based on the DIA (Declaration of Environmental Impact, dated 9 January 2002) in order to deal with the acoustic impact of the opening of the third runway, the new joint use of the three runways, the new takeoff and landing patterns, and the significant increase in air traffic that these involve. In March 2005 AENA and the Technical University of Catalonia (UPC) signed a collaboration agreement to develop this Acoustic Insulation Plan. This document details some of the preliminary conclusions of the architectural team relating to the impact of aircraft noise on buildings.

BACKGROUND
At the time of the start of construction of the new extension to Barcelona airport (El Prat), the Executive Office of the Barcelona Plan (OEPB), depending on Spanish Airports and Air Navigation (AENA), was set up to manage all works related to this extension. The OEPB developed a specific Plan for Acoustic Insulation derived from the DIA (Declaration of Environmental Impact, dated 9 January 2002) in order to deal with the acoustic impact of the opening of the third runway, the new joint use of the three runways, the new takeoff and landing patterns, and the considerable increase in air traffic that these involve. The plan was submitted to the Environmental Monitoring Commission for the Works of the Barcelona Plan.

Using computer programs to simulate acoustic impact based on predicted flight operations, the OEPB established the acoustically affected area delimited by isophonic lines corresponding to the new sites of Barcelona Airport operations. These represented acoustic levels at or above 65 dB (A) during the day (7-23 h) and 55 dB (A) at night (23-7 h), approved by the Environmental Monitoring Commission on 11 December 2003.

In March 2005 AENA and the Technical University of Catalonia (UPC) signed a collaboration agreement to develop this Acoustic Insulation Plan. This document details some of the preliminary conclusions of the architectural team relating to the impact of aircraft noise on buildings. Under this agreement the actions approved by the engineering group (LEAM) and architectural group (CA1) were:

1.- The LEAM and CA1 teams of UPC were to compile applicable regulations concerning noise in the interior of houses in order to define appropriate objectives.

2. - The LEAM was to determine the current acoustic conditions of structures located within the limits of the acoustically affected area.

3. - The LEAM was to determine the profile of the aircraft noise spectrum.

4. - Recommendations were to be made regarding solutions for projects involving acoustic renovation of the buildings in question.

5. - CA1 was to carry out acoustic validation of proposed building renovation.

6. - CA1 was to verify final execution of all works and conformity with the approved project.

At the time of this communication, 37 buildings have been studied, comprising 50 buildings and 270 rooms requiring action to improve the sound insulation of their outer walls.

From the point of view of the CA1 group, a series of provisional value judgments can already be made based on the technical work carried out in collaboration between the Airport Administration (AENA) and the University (UPC).

Figure 1: Field measurement work

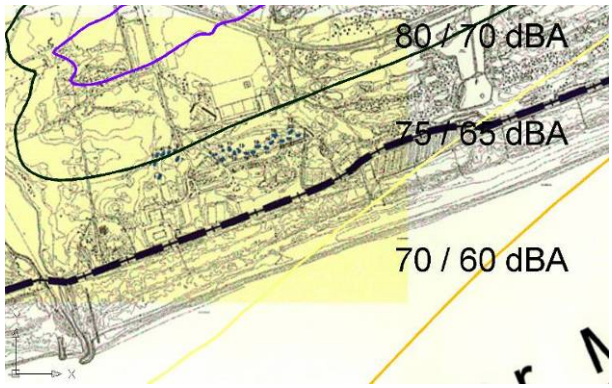

Figure 2: Isophonic map created using computer simulation

INTERPRETATION OF ISOPHONIC MAPS

Airport noise has been shown to be a source of environmental contamination that varies considerably according to time and place since airport operating conditions vary according to circumstances of market, climate, season and other factors.

In the coming years architects will need to develop expertise in consulting zonal noise maps and in taking account of conditions affecting the drawing up and updating of these maps in order to improve their ability to interpret them. In the current instance, it is necessary to add specifics arising from the displacement of the sound source (the aircraft), flight altitude, the affect of topographically flat areas, and situations in which an airport runway may be used under very different acoustic conditions, as in takeoff and landing.

Reference values drawn from numerical models and represented in 2D mapping with isophonic lines at 5 dBA intervals must be interpreted with great caution. In this case the use of isophonic lines providing very precise resolution was initially chosen in order to allow specialists to take into account the conditions that have an impact on all the affected buildings. A parallel study involving numerical simulation is currently being carried out by the LEAM of the UPC to evaluate the results of using more precisely delimited isophonic lines for facades directly exposed to the sound source and a lower resolution for the facades that are not directly exposed.

PROTECTION OF THE LOCAL BUILDING STOCK

The built up area around Barcelona airport located within the acoustically affected area includes isolated buildings for agricultural use. In some cases there has been a change towards tourist or second residence use, owing to the extraordinary character of the surroundings. These constructions were built at the end of 19th century and during the 20th century to facilitate

malaria control and establish a stable population in the delta. Many of the buildings visited by UPC have auxiliary premises that cannot be considered inhabitable either as dwellings or workplaces.

Spain has until recently maintained a tradition of construction based on structures with very thick architectural elements: solid structures employing few rigid materials or isostatic joints. In agricultural surroundings, as in the case of Barcelona airport, such structures provided adequate sound insulation, as some of the inhabitants interviewed freely attested. However, the most recent constructions in the area have been built using thinner materials, elements with air chambers, more rigid materials, and hyperstatic joints. Furthermore, the development of this area has paralleled the increase in airport traffic. Thus, in comparison with the older structures, the inadequacy of the more recent constructions in relation to the new acoustic conditions is evident.

A number of unique architectural works, protected by city planning and catalogued as local monuments, have been identified. In these cases, it has been recommended that any construction required be carried out by architects with appropriate expertise, with advice on acoustics being provided by the CA1 group of UPC. All of this wide range of properties is exposed to aircraft noise.

A DUAL TASK OF RENOVATION AND INSULATION

Earlier fears have been confirmed by field work: most of the buildings currently affected by Barcelona airport do not fulfil the Spanish regulations (at the date of this writing, NBE CA 88, a regulation that does not take into account diverse external acoustic conditions).

We thus faced a dual task: to renovate the buildings in conformity with the specifications that have been in place for nearly 10 years, and to protect them from the increase in airport noise so that the maximum background noise level permitted for the activities involved is not exceeded. This action involves costs and alterations to the buildings that are not the sole responsibility of the aircraft noise.

THE INTERIOR AND EXTERIOR FORM RATIO OF THE BUILDINGS

During the subsequent study of the impact of aircraft noise on the buildings under consideration, recurrent circumstances were noted that pointed towards possible actions to protect the buildings from the acoustic impact.

The first such factor was the importance of the form ratio of the exposed volume. Buildings with a large surface area of façade and roof in relation to their interior volume were extremely difficult to insulate despite the new technologies that are available. It has been noted that compactness should be encouraged in buildings sited in noisy surroundings and in any new architectural project.

A second factor was the importance of useless or “secondary” spaces in the interior layout of buildings. Dwellings that have transitional spaces (galleries, corridors, lobbies, attics, distributors, etc.) reveal that such auxiliary spaces act as protective acoustic barriers. However, in the "modern", loft-type interior layouts which are ubiquitous in tourist apartments, the use of a single inhabitable space represents an enormous difficulty in terms of the effective functioning of sound insulation. It has been noted that a complete differentiation of interior spaces must be encouraged in noisy surroundings, and this type of layout should be encouraged as a topological virtue in any architectural project.

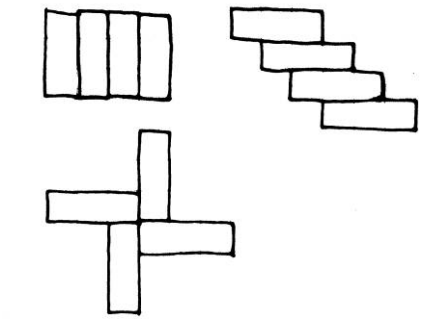

Figure 3: Varying form ratios

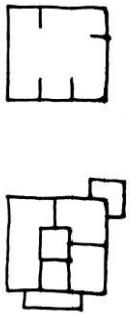

Figure 4: Varying compactness of layout

WINDOWS, A KEY ELEMENT

Though they are technologically simple, traditional wooden windows featuring small openings and panes with inner closures show comparable results in comparative acoustic measurements to conventional aluminium and commercial glass windows with roller blinds. We must note in addition that Annex 9 of the Catalan Noise Act requires the installation of windows complying with a minimum acoustic quality determined solely by the exterior noise level.

Consequently, in most cases it was necessary to recommend complete window replacement. In specifying the characteristics of the new windows, the inadequate level of development of the domestic market regarding acoustic conditions was noted: few certified products exist, supply levels are low, few industrial manufacturers are prepared to market suitable products, and there is a great acoustic divide to be crossed in the design of suitable roller blinds for complicated acoustic environments.

As a consequence of these difficulties of the window market, the alternative frequently considered less annoying to inhabitants, with a lesser constructive impact on buildings, is the acoustic reinforcement of existing windows with additional exterior windows. The installation comprising two separated windows, one old, one new, with an ample acoustically treated air chamber, represents a fundamental change in the hygrothermal behaviour of the architectural cavity. Systems using dual windows, one flush with the exterior plane, have led to the appearance of new "greenhouses" on the façades that act as thermal receivers as well as concentrators of condensation in the space between the two windows. These effects vary according to the characteristics of the ventilation system used, so the inhabitants of the Mediterranean area need to be informed about the use of this dual window system to avoid anomalies arising from inappropriate use.

NEW ROOFS

One of the issues of greatest concern is the acoustic quality of the roofs of the buildings. In the case of aircraft noise arising from airport use this is especially delicate since the sound source is at a high altitude. The roofs of the buildings studied are usually light and made of materials with few rigid joints, and their acoustic behaviour has been found to vary considerably. Few references are found in the technical literature concerning the performance parameters of these materials. There is thus great scope for innovation and experimentation in new roofs as a result of new design requirements such as those arising from climate change and increased use of photovoltaic energy.

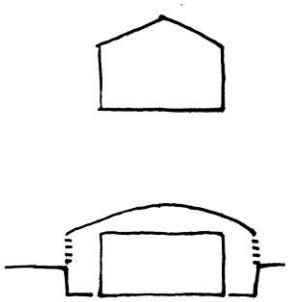

Figure 5: Traditional roofs and environmental roofs

QUALITY CONTROL AT THE WORK SITE

In initial phases of work on building sites, it has been found that conventional construction workers are not suitably trained for this new type of acoustic construction. On work sites, the CA1 team of the UPC has had to reiterate advice concerning good practices in carrying out acoustic installations. Such practices (unaligned joints, non-rigid connectors, installation of viscoelastic materials, dealignments, etc.) are not yet ingrained in the habits of construction workers.

To determine the homogeneity of the quality of works carried out, measurements were made of acoustic insulation in finished jobs. Variations in quality of up to 10 dBA were found in the same building. We must therefore consider the need to establish performance criteria for sound insulation and establish a quality control system based on:

- A weighted decrease in the acoustic insulation values stated by manufacturers based on laboratory values.
- A weighted increase in the impact values provided by noise maps.
- The possible establishment of "characteristic" insulation values for buildings based on a series of in situ measurements.

CONCLUSIONS

The collaboration between the Airport Administration and the University is proving to be especially fruitful in the case of the Plan for Acoustic Insulation of Barcelona airport since for both parties it represents an exceptional experience in applying the new standards and protocols for sound insulation in a large number of situations.

In the short term it seems unlikely that aircraft noise will diminish or have a lesser impact on our lives, so suitable treatment of this issue by architects will represent a challenge comparable to the protection of buildings from wind or earthquakes.