Evaluation of the Environmental Comfort Conditions in a Large Apartment Building

The COPAN study case, São Paulo, Brazil

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ABSTRACT: Designed by Oscar Niemeyer in the early 1950s, the Copan Building in downtown São Paulo, Brazil, was erected during a period when sweeping changes were taking place in the city. The local economy was strengthened by the growing real-estate market and was bringing about a veritable "rage of construction." The Copan is the tallest residential building in Latin America, having 116,152m² of constructed area, and it was a monument to the new architectural paradigms being adopted in São Paulo in the 1950s, including gigantism, verticalization and demographic densification. Using methods and techniques of the Post-Occupancy Evaluation (POE), this paper is aimed at appraising the building's performance in the environmental comfort: thermal and acoustic performance of the apartments and their natural lighting. Whenever possible and pertinent, and based on the diagnoses drawn up, recommendations are made to contribute to improving the quality of life in this building
Keywords: Post Occupancy-Evaluation, Environmental comfort, Large apartment buildings.

INTRODUCTION

Figure 1 – Aerial view of São Paulo city – Photo credit: SMPB/Projects by Eduardo Aquino

The Greater São Paulo Region, in southeastern Brazil, is the largest metropolitan area in South America, and has a total population of 17.8 million According to the Brazilian Census Office (IBGE) - www.ibge.org.br (22 August 2008). One of the outstanding characteristics of the Greater São Paulo Area has been its relatively recent growth. In 1950 it had 2.6 million inhabitants and, during the 1960s, intense demographic growth took place, thrust ahead by rapid industrialization. As part of the same process, the real-estate market also went through unprecedented growth. Technological inroads with the widespread use of reinforced concrete had already begun in the 1920s, and gave support to the new urban model of verticalization. Taller and taller buildings went up as a sign of São Paulo's enormous desire to be counted among the great cities in the world. One of the icons of this period is the Copan Building, located in downtown São Paulo. With its 1,160 apartments, this building includes a number of characteristic concepts of modern architecture, such as the use of sun-control devices and curtain facades.

In the 1960s, many residential buildings in São Paulo began a process of deterioration as part of the gradual decline in the downtown section of the city, and the Copan Building was no exception. Since the 1990s, however, the building went through a process of renovation.

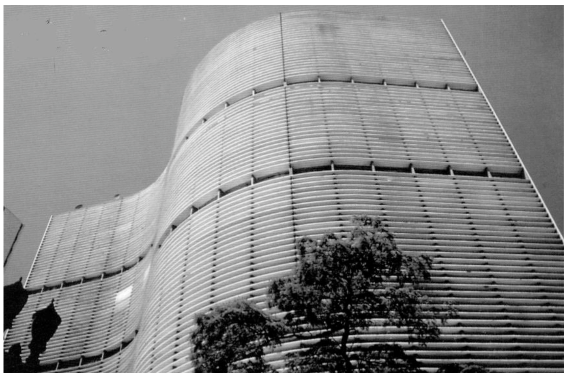

Figure 2 – COPAN building – Photo credit: Sergio Deher.

This article results from research related to the preparation of a master's thesis presented to the Faculty of Architecture and Urbanism of the University of São Paulo [1]. The objective is to appraise the Copan Building in one of its most important aspects of performance: environmental comfort in the apartments. The main focus of interest was the thermal and acoustic performance of the apartments and their natural lighting. The study was based on the principles of Post-Occupancy Evaluation (POE), defined as a set of methods and techniques which seek to verify whether the built environments in a building are truly addressing their users' expectations. Based on these diagnoses, recommendations are presented for the case study itself and possibilities are opened up for similar designs in the future [2, 3].

CASE STUDY

The Copan Building consists of a residential tower 32 floors in height, having a commercial area on the ground floor with 73 shops, a movie theater and two underground levels for parking. The apartments are distributed into six blocks, designated as Blocks A to F, and four sections, when defined by the structural joints (Fig. 3). Block A has 64 two-bedroom apartments, Blocks B, E and F have 968 kitchenettes and one-bedroom apartments, and Blocks C and D have 128 three-bedroom apartments.

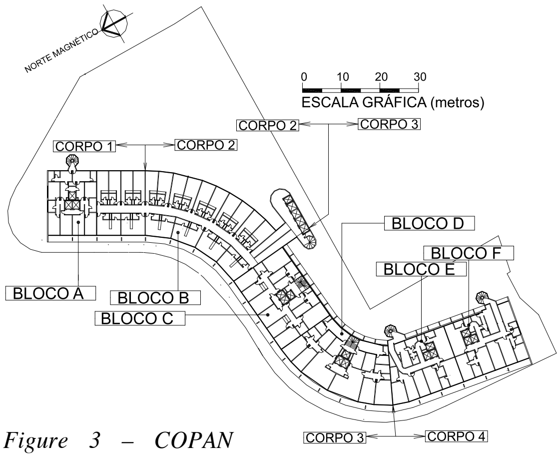

Figure 3 – COPAN building plan.

As was mentioned in the introduction, the Copan Building is located in downtown São Paulo, situated at latitude 23°37'S and longitude 46°39'W. The city's average altitude is 802 meters above sea level (3). Its climate is high-altitude tropical, with average temperatures ranging from 18ºC to 22ºC, but factors such as high demographic density, intense verticalization and pollution, among others, may also cause climate changes. Analyzing the bio-climactic chart with strategies indicated for São Paulo [5], it can be seen that 27.1% of the hours during the year are comfortable and 72.8% are uncomfortable, due either to cold (59.3%) or to heat (13.4%).

São Paulo has averages of illuminance on facades that vary from 6,700 lux – southern facade on the winter solstice - to 29,200 lux – northern facade on the summer solstice [6].

The traffic on the streets surrounding the Copan Building is moderate. According to the occupants, there is heavy traffic between 5:00 p.m. and 7:00 p.m., but motorists use their horns only rarely. Most traffic consists of buses and automobiles, the streets are level, and the cars usually decelerate as they approach nearby intersections. There is only one nightclub in the vicinity of the Copan Building, and two restaurants on the ground floor which rent space for parties in the mezzanines on Friday and Saturday nights. The daytime movement of pedestrians is intense but relatively quiet on nearby streets, but street vendors cause some of the local noise, although the bank building across the street from the Copan serves as an efficient sound barrier. These observations were made between April and August, 2004.

There are also sound barriers near Blocks A and B of the building. One of these barriers consists of an office building 30 meters away, its roof being the same height as the 20th floor of the Copan. The apartments in the rear have a compact barrier of buildings (Fig. 4).

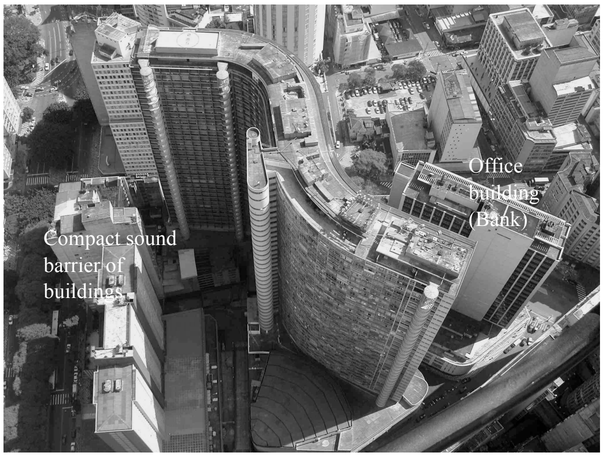

Figure 4 – Aerial view of COPAN building – Photo credit: SMPB/Projects by Eduardo Aquino

It should be noted that the bathrooms in the apartments do not have windows, but only air vents, and the walls are made of clay bricks covered over with plaster on both sides.

METHODS AND TECHNIQUES

Diagnoses based on the POE are the result of a process of crossing data from the two parts that comprise the instrument (evaluation of users satisfaction, and evaluation of physical performance). Based on these diagnoses, recommendations are presented for the case study itself and for similar projects in the future [2, 7]. The methodological procedures applied are described below.

EVALUATION OF USERS SATISFACTION

POE questionnaires were used to obtain information from them. An instrument with 35 questions was applied. Questions 9 to 29 constituted scales of verbal evaluation, Presentation of the possible responses to the items on the questionnaire, ranging from most favorable to most unfavorable, with categories organized on the basis of verbal expressions [8], including four variables ranging from "Very bad" to "Excellent," with "Bad," "Good," and "Does not apply" being other alternatives. Questions 11 to 16 were related to environmental comfort.

Three sample groups were employed: 1) Occupants of Blocks A, C and D; 2) Occupants of Block B; and 3) Occupants of Blocks E and F. For all these groups a stratified random sample was chosen, and half of the questionnaires were applied at apartments from the 1st to the 16th floors and another half above the 16th floor. The questionnaires were applied only to occupants who had lived in their current unit for at least one year. Thirty-three valid questionnaires were returned from Blocks A, C and D, 44 from Block B, and 30 from Blocks E and F (all were distributed and tabulated between November 2002 and March 2004).

To tabulate the data, numerical values were attributed to each response option as follows: "1" for Very bad, "2" for Bad, "3" for Good and "4" for Excellent. The "Does not apply" response corresponded numerically to "0" and was therefore not tabulated.

EVALUATION OF PHYSICAL PERFORMANCE

The physical evaluation of environmental comfort was based on on-site inspections and simulations using the Architrop, *Luz do Sol* (Federal University at São Carlos, State of São Paulo) and Relux (Relux Informatik AG - Switzerland) softwares. The Architrop software simulates inside temperatures of environments according to the outside climactic conditions in the building's vicinity. The Luz do Sol and Relux softwares indicate the amount of direct sunlight falling on environments and the indoor lighting, respectively.

Thermographs and Minipa Model MLM 1332 digital light meters were used to measure the air and light inside the environments. Statistical measurements were also made in dB (A), using an SL-4001 Lutron sound-level meter.

The data obtained from the measurements with the thermographs were compared with those of the outside air temperature on the same days, provided by IAG/USP (Institute of Astronomy, Geophysics and Atmospheric Sciences, University of São Paulo), which has a meteorological station at its campus in the same city.

For natural lighting the criteria for performance were illuminance levels for residential environments, pursuant to NBR Norm 5413/1992 [9] (150 lux), or overshadowment (Failure of the human eye in adapting to excessive contrasts. Can be disturbing or disabling [11]).

The data obtained from the measurements of noise levels were tabulated, and produced values of L10 (Sound pressure level exceeded for 10% of total measuring time.), L90 (Sound pressure level exceeded for 90% of total measuring time) and Leq (Level of equivalent sound pressure) which were compared with the provisions of Municipal Law 11.840 (São Paulo Municipal Government) and of NBR Norm 10.151/1987 [10].

RESULTS - EVALUATION OF USER SATISFACTION LEVELS

For the samples of respondents from Blocks A, C, D, E and F the percentages of responses of "Excellent" and "Good" surpassed "Bad" and "Very bad" in all the items studied. Only in the sample of respondents from Block B in Item "Summer temperature" was there a tie between responses, in other words, 50% responded "Excellent" or "Good" and 50%, "Bad" or "Very bad." It can also be seen that, in this sample, there was a significant reduction in the percentage of "Excellent" and "Good" (54%) responses to the Item "Ventilation in the apartments," in comparison with Blocks A, C and D (97% "Excellent" and "Good") and Blocks E and F (80% "Excellent" and "Good").

Of the population in Blocks A, C and D, 8.5% mentioned the "night club" as the item of greatest dissatisfaction, and 17% added "Noise from outside or from the street." One problematic item, namely, "Noise from the street and outside area", was referred to by 51.5%, and 15% complained of "Interference due to noise made by neighbors."

In the sample in Block B, 34% indicated "Noise from the street and outside area" and 38.6% referred to "Interference due to noise coming from neighbors" as a problematic point. Of the occupants in this sample 16% mentioned "Noise, Noise from the street or Noise pollution" as drawbacks related to living in downtown São Paulo.

In the sample of occupants of Blocks E and F, 33% indicated "Noise from the street and from outside" as a problem and 20% referred to "Interferences related to noise from the neighbors." In addition, 17% of this sample mentioned "Noise, Noise pollution or Noise at night" as disadvantages to living downtown.

Users in Blocks A, C, D, E and F give a positive evaluation to the item "Temperatures in the apartments in the winter and in the summer". But in Block B the item "Temperature in the apartments during the summer" is ambiguous.

In all the samples the items "Ventilation in the apartments" and "Contribution from natural light in the apartments" showed positive evaluations in the users' opinion.

The item on "Interference by noise from the street and outside area," is mentioned as a negative aspect in the written responses submitted by respondents in all the sub-samples. It can thus be concluded that the appraisal of the users is negative. In contrast, the item on "Interference from noise from the neighbors" is positively evaluated by the users.

EVALUATION OF PHYSICAL PERFORMANCE

The sun-control devices in the Copan Building block out much of the direct sunlight in the environments both in mid-summer and mid-winter. Analyzing the outside obstruction masks in Blocks C and D, it can be seen that the sun shines directly into the environments between 7:00 a.m. and 9:30 a.m. on the winter solstice in Block D, and between 7:00 a.m. and 8:30 a.m., and between 3:30 p.m. and 5:00 p.m. in Block C (Fig. 5).

Figure 5 – Window of an apartment of C block at 10:30pm in the winter day –Photo credit: Walter Galvao.

Besides the protection provided from the sun-control devices, the bank building protects the apartments in Block A and 90 of the 192 front apartments in Block B (from the first to the fifteenth floor) from direct sunlight. This fact means that the inside temperature in these front apartments does not rise as intensely as the outside temperature, a fact that is clear in the results of the measurements made in the apartments. The inside temperatures stay regular without extreme or rapid oscillations because the heat is not lost in the way it is lost outside.

The apartments at the rear of Block B face south and southeast and, like the front apartments, have curtain facades but no sun-control devices. The simulation shows that, on a typical summer day there is an increase in the inside environmental temperature (According to the Architrop Software Manual, environmental temperature is defined as the combined effect of air and surface temperatures). In the apartments that receive direct sunlight between 6:00 a.m. and 6:00 p.m. the indoor temperature is sometimes higher the outdoor temperature. It should be noted that during the simulation closed windows were considered during the morning period, annulling the effects of the ventilation.

The apartments in Blocks A, C and D have good ventilation because they extend from one side of the building to the other, thus facilitating cross ventilation. In Blocks B, E and F, where the kitchenettes and one-bedroom apartments are located, the units do not extend across the building, and this reduces the ventilation. On the weekend of 11 and 12 December 2004, the temperature in numerous rear kitchenettes in Block B was measured with the hall doors open, to see if the ventilation in these apartments could be improved.

Another fact observed was the low quality of the window frames (The window frames in the Copan Building were manufactured and installed in the 1950s and were made of iron and common glass 4mm thick. Each frame holds two stationary blinds and two sliding shutters), which, even when closed, let the cold air slip through. This, of course, worsens the performance of the apartments in Blocks A, C and D in the winter.

The apartments in the Copan Building that face north and northwest receive good lighting from outside on vertical planes. But some units, such as the rear kitchenettes in Block B, do not receive as much natural light as those facing north and northwest. Quantitatively, the environments in the front apartments, which have sun-control devices, and those in the rear without sun-control devices (Block B) or with open bricks (Blocks E and F), have average illuminance above the 150 lux indicated in NBR Norm 5413/1992. But the apartments in Blocks A, C and D all have a bedroom with a window facing the service area, where the illuminance proved to be much lower than that provided in the above-mentioned norm. The same problem exists in the kitchens of these apartments.

None of the bathrooms in the apartments have openings to the outside. They have only a 20x20cm grate for mechanical ventilation. The use of these environments thus requires artificial light even during the day. None of the bedroom windows in the apartments have any device to control (Device especially designed to regulate admission of light through a passageway) the light, such as venetian blinds (Control devices consisting of a series of stationary or sliding structures arranged externally, which completely cover over the outside of an opening). This means that the illuminance can be as high as 100 lux as of the first hours of sunlight, causing irritating problems of light coming in and prejudicing the sleep of those who have not yet risen.

The first three measurements in the foyer, made during the night of 28 to 29 August, 2004, showed that the L10 varied from 63 to 64 dB(A), the Leq, from 62 to 63 dB(A) and the L90, from 59 to 60 dB(A). In all three cases the Leq was far above that provided in São Paulo Municipal Law 11.804 (Regulates the acceptable noise levels in the City of Sao Paulo, aimed at guaranteeing the community's tranquility) for "mixed areas intended for commercial and administrative use," that is, 60 dB(A) during the day and 55 dB(A) at night. It was noted that the nighttime traffic on the surrounding streets was calm, consisting mostly of automobiles, and there were a great many persons at the entrance to the night club. But the greatest sources of noise were the two restaurants located on the ground floor of the Copan itself, which are among the few commercial establishments in the gallery that remain open after 11:00 p.m.

Measurements showed that the standard window frames of the front apartments have insulation capacity of 11db(A) from traffic noise. NBR Norm 10.151/1987 recommends a window-frame insulation capacity of 15 dB(A) as the result of the difference between the outside and internal measurements of a closed window: areas with both commercial and administrative use – daytime outside level is 60 db(A) and daytime indoor level with windows closed is 45 db(A). In other words, these window frames in the front have low insulation capacity, since the noise level measured - 11 dB(A) – was below the recommended levels mentioned in NBR Norm 10.151/1987.

DIAGNOSIS

The specialists noted that, during the winter, the thermal performance in the front of the building is inadequate. For the item on questionnaire entitle "Temperature in the winter," however, only 21% of the users/occupants of the sample marked choices "Bad" or "Very bad." In contrast, 27% indicated "Temperature in the winter" as one the problems of the apartments. It should be recalled that the questionnaires were applied during the hottest months of the year. The questionnaires for Blocks A, C and D were applied between November and April (the average temperatures in 2004 in São Paulo were January, 23°; February, 24°; March, 23°; April 21°; May, 19°; June, 18°; July, 17°; August, 18°; September, 18°; October, 21°; November, 22° and December, 22°-http//br.weather.com, Nov. 2, 2005).

Both the specialists and the users agree on the inadequate thermal performance in both summer and winter in the rear apartments of Block B. Even though the questionnaires were applied during the summer (January), 18% of the users/occupants responded "Bad" or "Very bad" to the item entitled "Winter temperature in the apartments."

Even though the responses indicate a positive trend in the item on "Ventilation in the apartments," in Block B this item received one of the lowest ratings from users. Even in Blocks E and F, 20% of the users/occupants responded "Bad" or "Very bad" to this question. But in Blocks A, C and D "Ventilation in the apartments" received one of the highest ratings from the users. This fact reinforces the opinion of the specialists that indicate that the apartments in Blocks A, C and D have good quality ventilation, in contrast to the low ratings in Blocks B, E and F, where there is no cross ventilation.

Specialists and users agree that the majority of the 2- and 3-bedroom apartments, as well as the kitchenettes and 1-bedroom apartments, have adequate natural lighting. In the kitchens and bedrooms at the rear of Blocks A, C and D, however, the opinion of the specialists is confirmed, with illuminance below that determined by NBR Norm 5413/1992. The problem of the bathrooms without windows, detected by the specialists, may contribute to the presence of mildew and fungi in these environments, due to the fact that such organisms survive in damp, unventilated places, especially where there is no natural light (www.ipibrasil.com.br (25 May 2005)). The lack of equipment to control the light that falls on the bedroom windows confirms the specialists' opinion as to the discomfort caused to occupants who sleep beyond daybreak, in view of the fact that too much light is one of the causes of sleeping disorders [11].

Specialists and users all agree that the window frames in the Copan Building are inadequate in terms of acoustics. It was noted that the only nightclub in the neighborhood did not represent a considerable source of noise, even though there were a good many people gathered at the door of the nightclub during the inspection. Although the nightclub was mentioned by the sample of respondents in Blocks A, C and D as a major source of nighttime noise, this dissatisfaction seems due more to the moral opinions of many of the occupants regarding the proximity of this type establishment, than to the noise itself. It should be noted that Blocks A, C and D have the largest apartments (2 and 3 bedrooms) and are inhabited by users of higher income brackets.

Even though all the samples of respondents of the questionnaires positively rated the item entitled "Interference from noise caused by neighbors," the ventilation ducts of the bathrooms are definitely an important channel for noise between one apartment and another. In the sample in Block B, where most of the building's kitchenettes are located, 38.6% of the users/occupants indicated “Interference by noise from neighbors” as a problem of their unit. There are fewer acoustic barriers between the bathrooms and sleeping quarters in the kitchenettes than in the 3-bedroom apartments.

CONCLUSION

The Copan Building leads architects to reflect on the true efficiency of sun-control devices in residential buildings in São Paulo. But to attenuate the effects of the city's climate, which, as mentioned above, is tropical and at a relatively high altitude, specifications for sun-control devices must be carefully calculated in order to avoid blocking out the sunlight on cold winter days. To ventilate such environments in São Paulo, the principle of cross ventilation with openings through opposite walls should be combined with some type of control of the air currents in order to avoid excess cold in the winter.

In terms of natural lighting in residential buildings, it is important to employ light-control mechanisms, such as curtains or persian blinds in social areas, as well as venetian blinds on the outside of bedroom windows. Curtains deflect direct sunlight and adjustable venetian blinds resolve the problem of the disturbing overshadowment (Failure of the human eye to adapt to excessive contrasts that it can be disturbing or disabling – [12]) generated by the strong light that comes into the apartments in the early morning. Occupants spend most of their home time in their bedrooms and special care should therefore be taken to decide on the strategies to guarantee the best use of natural lighting. Even though bedrooms today are employed for a wide variety of uses, we cannot forget that their main function is to provide rest. Thus, the existence of adjustable mechanisms to control natural lighting is as important as the correct sizing of the openings for light to enter. Besides the problem of mildew and fungi, as mentioned earlier, the absence of openings between the bathrooms and the outside means that artificial light must be used, even during the day. The existence of windows that would allow the natural light to enter would undoubtedly result in lower energy costs.

Even though disturbances resulting from noise in large cities is not a new problem like in Moles [13] had already related the increase in noise levels to which urban dwellers were submitted, to industrial growth in large cities, only in recent years have laws been enacted in Brazil to regulate emissions of noise and to impute responsibility to constructors for the positive or negative aspects of noise in buildings, pursuant to CONAMA Resolution No. 001 (National Environmental Board) and to the Consumer Defense Code, both of 1990. Even with this legal backing, the quality of constructions in terms of acoustic comfort has worsened over the years, with the use of lighter materials in joints, walls and slabs, designed to take weight off of foundations and reduce costs [13]. In specific reference to the present study, constructed in the 1950s, with the exception of problems with window frames and air vents in the bathrooms, as described above, the Copan Building shows good levels of acoustic insulation between environments and floors.

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